Russia's Military R&D Infrastructure

A Primer

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Sammanfattning

Rysslands militära FoU-infrastruktur består av tre typer av organisationer med rötter i Sovjettiden – forskningsinstitut, konstruktionsbyråer och vetenskapliga produktionsassociationer. Forskningsinstituten sysslar i huvudsak med att utveckla forskningsidéer för militär tillämpning. Konstruktionsbyråerna utvecklar och testar prototyper. Vetenskapliga produktionsassociationer kombinerar FoU-verksamhet med egen tillverkningskapacitet. Sammantaget består försvarsindustrins FoU-komponent av nästan 600 organisationer. Av dessa är cirka 300 forskningsinstitut, knappt 130 konstruktionsbyråer och ungefär 170 vetenskapliga produktionsassociationer.

Geografiskt är FoU-organisationerna koncentrerade till större städer. I och omkring Moskva finns nästan hälften av alla FoU-institut, medan St. Petersburg har en femtedel av instituten. Den militära FoU-strukturen kan indelas i sju huvudsakliga branscher: flyg, rymdteknologi, skeppsbyggnad, konventionella vapen, radioelektronik och kommunikationssystem, ammunition och speciella kemikalier samt kärnteknik. Därtill kommer nya prioriterade teknologiområden, som artificiell intelligens och robotik och autonoma system. Dessa är på väg att växa fram som egna branscher, men är i högre grad horisontellt organiserade på så vis att forskningen på dessa områden äger rum inom FoU-organisationer tillhörande samtliga traditionella sektorer.

Nyckelord: Ryssland; militär FoU, forskningsinstitut, konstruktionsbyråer, vetenskapliga produktionsassociationer, försvarsindustri, militärteknik, artificiell intelligens, militär autonomi, obemannade system.

Summary

Russia's military R&D infrastructure has long historical roots and consists of three main types of organisation – research institutes, design bureaus and scientific production associations. Research institutes primarily conduct applied research for the defence industry. Design bureaus engage in developing prototypes. Scientific production associations combine R&D facilities with their own production factories. Overall, the military R&D infrastructure consists of approximately 600 organisations. Out of these, there are about 300 research institutes, close to 130 design bureaus and roughly 170 scientific production organisations.

Geographically, the R&D organisations are largely concentrated in scientific industrial centres, which combine scientific research and production. Almost half of Russia's R&D entities are located in and around Moscow and almost one-fifth in St. Petersburg. Overall, Russia's military R&D can be divided into seven main branches: aviation; space technology; shipbuilding; conventional arms; radio electronics and communication systems; ammunition and special chemicals; and nuclear technology. In addition, the Russian government prioritises new critical military technology areas, such as artificial intelligence and robotics and autonomous systems. These are cross-cutting technologies with R&D initiatives taking place across the traditional branches. Nonetheless, the government has created several specific R&D initiatives to concentrate, streamline and speed-up technology development in these fields.

Keywords: Russia; military R&D, research institutes, design bureaus, scientific production associations, defence industry, military technology, artificial intelligence, military autonomy, unmanned systems.

Foreword

For Russia – a country with a defence industry that encompasses the entire range of research institutes, design bureaus and manufacturing plants – military research and development (R&D) is of substantial weight for military capability. Military R&D is nonetheless a difficult area to assess. R&D on complex technologies for military applications may take decades to yield fruitful results. In this report, Johan Engvall advocates a return to basics by mapping and categorising Russia's vast military R&D infrastructure. He also identifies and discusses how the Russian government organises R&D in prioritised new technology areas. The conclusions reached in the report raise a number of questions that could become the subject of future research.

The Swedish Ministry of Defence has for more than 20 years commissioned analytical work from the Russia and Eurasia Studies Programme at the Swedish Defence Research Agency (FOI). This report is part of FOI's continuous efforts to analyse key aspects of Russian military power and its implications.

We are indebted to Edward Hunter Christie, former Deputy Head of NATO Innovation Unit, for his thorough and thought-provoking review of the draft report. His recommendations not only helped improve the report, but also provided direction for future work on the topic. FOI colleagues Fredrik Westerlund, Tomas Malmlöf, Gudrun Persson, Carolina Vendil Pallin and Pär Gustafsson all read and generously shared their reflections on the draft of this report. Mattias Hjelm designed the map and Richard Langlais, language-edited the report.

Johan Norberg

Head of the FOI Russia and Eurasia Studies Programme

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Contents

List of figures

List of tables

List of abbreviations

766 UPTK	766 Office of Production and Technical Completion (*766 upravlenie proizvodstvenno tekhnologicheskoi komplektatsii*)
AI	Artificial Intelligence
C2	Command and Control
DARPA	US Defense Advanced Research Projects Agency
EW	Electronic Warfare
FPI	Advanced Research Foundation (*Fond Perspektivnykh Issledovanii*)
GosNIIAS	State Scientific Research Institute of Aviation Systems (*Gosudarstvennyi nauchno-issledovatelskii institute aviatsonnykh materialov*)
GPV	State Armament Programme (*Gosudarstvennaya programma vooruzheniya*)
ISR	Intelligence, Surveillance and Reconnaissance
KB	Design Bureau (*Konstruktorskoe byuro*)
MBT	Main Battle Tank
MIT	Ministry of Industry and Trade of the Russian Federation
MoD	Ministry of Defence of the Russian Federation
NII	Research Institute (*Nauchno-issledovateslkii institut*)
NIIME	Research Institute of Molecular Electronics (*NII Molekulyarnoi Elektroniki*)
NIOKR	*Nauchno-issledovatelskie i opytno-konstruktorskie raboty*
NPO	Scientific Production Association (*Nauchno-proizvodstvennoe obedinenie*)
OKB	Experimental Design Bureau (*Opytno-konstruktorskoe byuro*)
R&D	Research and Development
RAS	Russian Academy of Sciences
TsNIIMash	Central Research Institute of Machine Building (*Tsentralnyi nauchno-issledovateslkii institut Mashinostreoniya*)
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UUV/USV	Unmanned Underwater/Surface Vehicle
VIAM	All-Russian Scientific Research Institute of Aviation Materials (*Vserossiiskii nauchno-issledovatelskii institut aviatsonnykh materialov*)

1 Introduction

Military power is vital to international security. In the longer term, military prowess to a significant extent rests on technology development and innovation.[1] Ever since the introduction of the machine gun, the lethality of weapons has trumped the quantity of armament.[2] The Russian Federation is a regional military power with global aspirations. It is one of a handful of countries with the ambition to keep a defence industry covering the entire line of military systems, platforms and equipment for all branches of its military and security forces.[3] Russia's defence industry encompasses every stage of the process, from research and development (R&D) to serial production. For the future transformation of Russia's military capabilities, the government has renewed its focus on defence-related R&D. Russian military R&D is therefore of interest for those taking a broad interest in long-term international security as well as those taking a specific interest in Russia.

There is a lacuna regarding research on Russia's military R&D infrastructure.[4] Overall, analyses of Russian R&D, including defence-related R&D, tend to fall under one of two categories. On the one hand, some analysts argue that Russian research has been in permanent crisis since the 1990s. They stress that a litany of factors, including lack of investment, shortage of human capital, brain-drain, and systemic corruption, hampers Russia's technology development and innovation efforts.[5] On the other hand, other commentators take a more optimistic view, noting that more policy attention and resources are devoted to the exploration of a range of new and advanced technologies with potentially far-reaching military applications.[6]

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[1] RAND, *Measuring National Power in the Postindustrial Age*, Santa Monica, CA: RAND, 2000.

[2] Stephen Biddle, *Military power: Explaining Victory and Defeat in Modern Battle*, Princeton: Princeton University Press, 2004.

[3] Tomas Malmlöf and Johan Engvall, "Russian armament deliveries," in Fredrik Westerlund and Susanne Oxenstierna (eds.), *Russian Military Capability in a Ten-Year Perspective – 2019*, Stockholm: Swedish Defence Research Agency – FOI, 2019, p. 115.

[4] For an overview of the evolution of Russia's military R&D during the first post-Soviet decade, see Jan Leijonhielm, Jenny Clevström, Per-Olov Nilsson and Wilhelm Unge, *Den ryska militärtekniska resursbasen: Rysk forskning, kritiska teknologier och vapensystem*, Stockholm: Swedish Defence Research Agency – FOI, 2002.

[5] Irina Dezhina, "New Science Policy Measures in Russia: Controversial Observations," *Russian Analytical Digest*, no. 155 (2014): 11-14; Michael McFaul, "The Missed Opportunity of Technological Breakthrough in Putin's Russia," Hoover Institution, Issue 118, 3 October 2018; John Herbst and Sergei Erofeev, *The Putin Exodus: The New Russian Brain Drain*, Washington, DC: Atlantic Council, 2019; Keith Dear, "Will Russia Rule the World Through AI?" *The RUSI Journal*, vol. 164, no. 5-6 (2019): 36-60.

[6] This relates in particular to artificial intelligence, robotics and autonomous systems, see for example Margarita Konaev and Samuel Bendett, "Russian AI-Enabled Combat: Coming to a City Near You?" *War on the Rocks*, 31 July 2019.

In contrast, analysts have directed much less attention towards systematically outlining the basic contours of the Russian military R&D landscape. This report seeks to fill this gap by mapping and classifying Russia's defence-related R&D infrastructure. The following research questions guide the report:

- How is Russia's military R&D funded and organised and what are its constitutive parts?
- What new technology areas are prioritised by the Russian government and how is R&D organised in these fields?

1.1 Data sources and methodology

According to the 2015 official registry of the Ministry of Industry and Trade (MIT), the Russian defence industrial complex (*oboronno-promyshlennyi kompleks*) consists of 1353 organisations.[7] The complex employs about 2 million people.[8] While no exact figures exist on how many scientists work in the defence industry, a recurrent estimate is that the sector engages half of the country's scientists and accounts for 70 per cent of all high-technology products.[9] Not all of these organisations and their human resources are involved in the development and production of weapons or other military hardware. Since 2015, some entities have closed down or merged, including a dozen R&D organisations, while some new ones have emerged. However, these changes seem to have only marginally altered the total number of organisations. Indeed, in 2018, the Russian government reported, without listing the entities, that the defence industry's consolidated registry consists of 1355 organisations, thus, giving a total count of two more organisations than three years before.[10]

To construct an approximate database of the defence industry's R&D component, MIT's register was reviewed for this study, in order to identify and separate R&D organisations from industrial enterprises mainly involved at the production stage. Overall, the review found that the Russian defence industry includes nearly 600

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[7] Ministry of Industry and Trade (MIT), "Ob utverzhdenii perechnia organizatsii oboronno-promyshlennogo kompleksa," *Prikaz no. 1828*, 23 July 2015.

[8] Pravitelstvo Rossii, "Oboronno-promyshlennyi kompleks. Gosudarstvennyi oboronnyi zakas: nekotorye fakty za 6 let," 11 April 2018. This can be compared to up to 5 million people working in approximately 2000 organisations during the last year of the Soviet Union. See D.K. Latyshenok, "Sovremennoe sostoyanie oboronno-promyshlennogo kompleksa Rossii," *Vestnik SibGAU*, vol. 16, no. 1, pp. 253-260 (254); Julian Cooper, *The Soviet Defence Industry: Conversion and Reform*, London: Pinter Publishers, 1991, pp. 12-14.

[9] Valerii Tsvetkov, "Oboronno-promyshlennyi kompleks Rossii: problemy i perspektivy razvitiya," 2016; Roger Roffey, "Russian Science and Technology is Still Having Problems – Implications for Defense Research," *Journal of Slavic Military Studies*, vol. 26, no. 2 (2013): 182.

[10] Pravitelstvo Rossii, "Oboronno-promyshlennyi kompleks".

R&D organisations.[11] These approximately 600 organisations can be classified into three distinct categories: research institutes; design bureaus; and scientific production associations.

There are approximately 300 research institutes (*nauchno-issledovatelskie instituty,* NII) that primarily conduct applied research for the defence industry, equivalent to just over 20 per cent of the approximately 1350 entities belonging to the defence industry. In addition, there are almost 130 design bureaus (*konstruktorskie byuro,* KB) or experimental design bureaus (*opytno-konstruktorskie byuro,* OKB) mainly working on the design and development of prototypes. Finally, there are around 170 scientific production associations (*nauchno-proizvodstvennye obedineniya*, NPO), i.e. organisations incorporating research, design and prototype development as well as industrial production. Thus, design bureaus and scientific production associations constitute approximately 10 per cent and 12 per cent of the defence industry, respectively.

In total, R&D institutes, defined as research institutes, design bureaus and scientific production associations, account for over 40 per cent of the total number of organisations belonging to the Russian defence industry. That said, it should be underlined that the data presented are approximate. An excerpt from the database of defence industrial R&D organisations within the particular branch of the shipbuilding industry is presented in the Appendix.

Of the approximately 750 remaining organisations, the vast majority, about 600, are production factories. There are also a number of shipyards, supply stores, repair centres, test sites and other entities belonging to the defence industry. While some manufacturers may have their own small research units, their primary purpose is to put designs developed by R&D facilities into serial production. This report, therefore, excludes all factories. Table 1 illustrates the approximate amount of R&D organisations and non-R&D enterprises (such as factories, repair centres, shipyards, etc.) in the Russian defence industry.

[11] At the time of the collapse of the Soviet Union, Julian Cooper estimated the number of research institutes and design organisations to lie somewhere in the span 600-800 establishments. Julian Cooper, *The Soviet Defence Industry*, p. 14.

Table 1. Approximate distribution of organisations in the defence industry[12]

Defence industry categories	Number of entities
R&D organisations	**600**
Research institutes	300
Design bureaus	130
Scientific production associations	170
Other (factories, repair centres, etc.)	**750**
Total	**1350**

In the registry, the majority of research institutes, design bureaus and scientific production associations can be identified by their formal names, such as the State Scientific Research Institute of Aviation Systems (*Gosudarstvennyi nauchno-issledovatelskii institut aviatsionnyh system*), Machine-building Design Bureau 'Raduga' (*Mashinostroitelnoe konstruktorskoe byuro 'Raduga'*) or Scientific Production Association 'Molniya' (*Nauchno-proizvodstvennoe obedinenie 'Molniya'*). However, several other R&D organisations lack such detailed names. Those organisations have instead been identified and classified on the basis of information obtained from their official websites or through extensive Internet searches.

1.2 R&D: definition, types and process

The OECD defines R&D as comprising "creative and systematic work undertaken in order to increase the stock of knowledge and to devise new applications of available knowledge."[13] R&D, in Russian *NIOKR* (*Nauchno-issledovatelskie i opytno-konstruktorskie raboty*), consists of three components – basic research, applied research and (experimental) development:

> **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. **Applied research** is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. **Experimental development** is systematic work, drawing on knowledge gained from research and practical experience and producing additional

[12] Author's database, created from MITs defence industry register.
[13] OECD, *Guidelines for Collecting and Reporting Data on Research and Experimental Development*, 2015, p. 44.

knowledge, which is directed to producing new products or processes or to improving existing products or processes.[14]

To specify further, basic research seeks to build knowledge in a more unconditional and complete manner without direct practical or commercial application, while applied research has directed objectives specified by a specific customer or industry. Experimental development, in turn, is research that generates knowledge and designs of prototypes to be converted into production at a stage when R&D has been completed. Thus, there is a basic process to R&D spanning from fostering, focussing and developing ideas (from basic to applied research phases) to designing, developing and testing prototypes (experimental development phase).

1.3 Limitations

Since this report serves as an introduction to Russia's military R&D, it adopts a narrow focus of quantitatively mapping and classifying the research infrastructure. Consequently, several interesting aspects fall outside the scope of the report. First, the report concentrates on military R&D. Civilian R&D and the relationship between civilian R&D and military R&D are discussed only in relation to dual-use technologies. Second, since the aim is to clarify and describe the military research infrastructure, the report makes no claim to be undertaking a thorough assessment of the overall quality and success of Russian military R&D efforts. Instead, it identifies a set of key questions that future research should address in order to reach more informed conclusions about whether Russia's military R&D infrastructure is fit for high-technology breakthroughs. Finally, the report focusses on describing Russia's military R&D structure. This means that there is no attempt to make point-by-point comparisons between Russia and other countries. In those few places where the report addresses other countries, they are discussed purely as a frame of reference.

1.4 Outline

The report adopts the following structure: Chapter 2 describes the military R&D infrastructure, with a focus on funding, organisation and the respective roles of military research institutes, design bureaus and scientific production associations. It also categorises this vast system of R&D entities by mapping its geographical concentration and branch-specific distribution. Chapter 3 analyses how the Russian government is organising its R&D efforts regarding the interrelated critical technology areas of artificial intelligence (AI) and autonomy. These two prioritised areas are cross-cutting and do not readily fit within the conventional branches discussed in the preceding chapter. Chapter 4 offers some brief concluding remarks before identifying a set of questions that could become the

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[14] Ibid, p. 45. Bold in original.

subject of future research in order to assess in detail the qualitative potential of Russia's military R&D in a forward-looking perspective.

2 Russia's military R&D landscape

Russia inherited the overwhelming majority, perhaps up to 80 per cent, of the vast system of research institutes, design bureaus and science cities of the Soviet Union.[15] In the 1990s and early 2000s, the Russian government aspired to redirect the high proportion of military research to civilian science and technology, but without much success. Over the past decade, the Russian leadership has increasingly emphasized military technology over civilian science and technology.[16] As one of the few technology-intensive sectors in which Russia enjoys a strong international position, the government perceives military R&D as a particularly promising source of technological innovation.[17]

2.1 Spending

Since large parts of the defence budget are classified, it is difficult to assess exactly how much Russia spends on military R&D. However, the sub-item of applied R&D in the defence budget suggests a minimum level of expenditures. For the period 2010-2016, spending on applied R&D grew steadily and almost doubled in real prices.[18] After peaking at 471 billion roubles, corresponding to 12.5 per cent of the defence budget in 2016, expenditures have decreased to some 10 per cent, or around 300 billion roubles, annually. Table 2 shows the level of spending and the share of applied military R&D in the defence budget from 2014 to 2018.

Table 2: Applied military R&D in billions of RUB and as % of defence budget[19]

	2014	2015	2016	2017	2018
Total national defence	2 47.1	3181.4	3776.2	2852.2	2827.0
Applied R&D in the field of national defence	244.6	318.5	471.3	270.5	324.9
Applied R&D in % of total national defence	9.9	10.0	12.5	9.5	11.5

[15] Lars B. Wallin (ed.), *The Post-Soviet Military-Industrial Complex, Proceedings of a Symposium*, Stockholm: Swedish National Defence Research Establishment, 20 October 1993, p. 13

[16] Yurii Abdeev, "Oboronka stala lokomotivom ekonomiki," *Krasnaya zvezda*, 28 May 2018.

[17] Una Hakvåg, "Russian Defense Spending After 2010: The interplay of Personal, Domestic, and Foreign Policy Interests," *Post-Soviet Affairs*, vol. 33, no. 6 (2017): 503.

[18] Institut ekonomiki rosta im. Stolypina P.A., "Rol oboronno-promyshlennogo kompleksa v obespechenii ekonomicheskogo rosta v RF," November 2017.

[19] Susanne Oxenstierna, "Russian military expenditure," in Gudrun Persson (ed.), *Russian Military Capability in a Ten-Year Perspective – 2016*, Stockholm: Swedish Defence Research Agency, 2016; Susanne Oxenstierna, "The economy and military expenditure," in Fredrik Westerlund and Oxenstierna (eds.), *Russian Military Capability in a Ten-Year Perspective – 2019*, Stockholm: Swedish Defence Research Agency, 2019.

Up to 2021, the share of spending on military R&D remained largely unchanged.[20] However, the severe economic impact of the Covid-19 pandemic might reduce military expenditures, and also have an impact on the future level of funding for military R&D.

If the level of spending on applied R&D, as stipulated in the defence budget, is combined with government spending on civilian R&D, the share of applied military R&D has amounted to at least one-third of total R&D funding.[21] In comparison, in 2016, the US spent more than 50 per cent of government-funded R&D on defence. In Europe, the UK devoted nearly 16 per cent of government R&D to defence, France over 6 per cent and Germany less than 3 per cent.[22]

While the bulk of defence-related R&D expenditure goes to applied research for the defence industry, Tor Bukkvoll, et al., have identified some sources of funding for basic research for military purposes. First, parts of the national budget for "Fundamental Studies" fund basic research for military purposes. Second, in 2012 the government established *Fond Perspektivnykh Issledovanii* (FPI), often translated as the Advanced Research Foundation, in order to facilitate the development of breakthrough high-risk R&D in the interest of national defence and state security. Third, the non-military federal target programmes, and the national projects announced in 2018, include some funding for basic research that may be beneficial for military applications. However, overall, the authors conclude that expenditures on basic research for military purposes pale in comparison to funding for applied military R&D.[23]

Since expenditures for military R&D are lumped together in a single sub-item of the defence budget, it is not possible to estimate the share of resources devoted to different military branches or specific technology areas. Besides direct funding for R&D, some of the spending on procurement, the major cost in the defence budget, goes to R&D work. An additional and highly significant source of funding for the defence industry's R&D comes from export revenues.

In sum, the Russian government's revived focus on military R&D has manifested itself through increasing levels of spending. However, by the beginning of the 2020s, the upward trend of funding appears to have plateaued. The future will tell

[20] Julian Cooper, "Military Expenditure in the Russian Draft Federal Budget for the three years 2019 to 2021: A Research Note," Changing Character of War Centre, Pembroke College, University of Oxford, 2019.

[21] This estimation is based on combining the level of spending on military R&D as stipulated in the defence budget with government spending on civilian R&D, statistically compiled in *Indikatory nauki*, Statisticheskii sbornik, Moscow, 2018.

[22] Congressional Research Service, "Government Expenditures on Defense Research and Development by the United States and Other OECD Countries: Fact Sheet," CRS Report Prepared for Members and Committees of Congress, 19 December 2018.

[23] Tor Bukkvoll, Tomas Malmlöf & Konstantin Makienko, "The Defence Industry as a Locomotive for Technological Renewal in Russia: Are the Conditions in Place?" *Post-Communist Economies*, Vol. 29, Issue 2 (2017): 3-5.

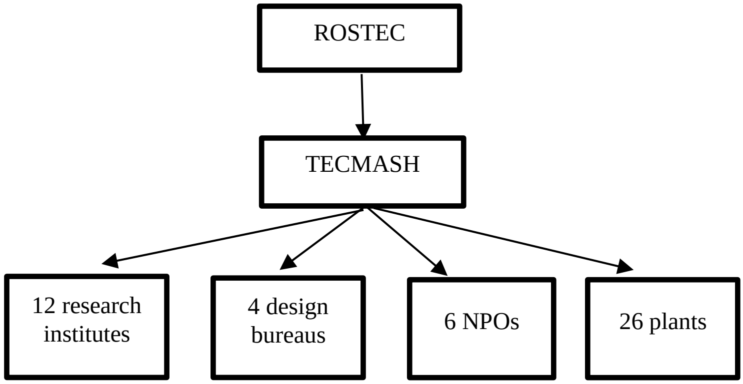
whether the level of funding established is sufficient to make the technological leap desired by the Russian political leadership. For the R&D and production enterprises in the defence industry, the main challenge moving forward will be to offset decreasing state contracts with output for the civilian market.[24] In other words, they need to learn how to make money on their own. The official defence-industrial strategy for the 2020s instructs the defence industry to convert 30 per cent of its output to civilian and dual-use products by 2025, and 50 per cent by 2030.[25]

2.2 General organisational structure

The collapse of the Soviet Union dealt a heavy blow to the defence industry and its R&D organisations. After the chaotic privatisation drive in the 1990s, the government under President Putin began to renationalize selected industries, including defence, in the mid-2000s. This resulted in the consolidation of state control of the sector in the form of vertically integrated holding companies. These holdings, often referred to as national champions, bring together many loosely connected enterprises.[26] At the very top of the pyramid is the state holding conglomerate *Rostec*, which controls most of the largest Russian defence industry corporations, such as United Aircraft Corporation, *Kalashnikov*, *Uralvagonzavod*, Russian Helicopters, High Precision Systems, and many others. Overall, *Rostec* controls more than 800 companies, consolidated into 15 holdings.[27] The organisational structure can be illustrated with the example of *Tecmash,* a holding company comprised of designers and manufacturers of artillery ammunition and special chemicals. *Tecmash* was established by *Rostec* in 2011, and by the early 2020s the company serves as an umbrella for 48 organisations in the ammunition and special chemicals industry. Of these entities, 47 belong to the defence industry, including 22 R&D institutes.[28] Figure 1 illustrates vertical integration with the example of *Tecmash*.

[24] Stanislav Rozmirovich, "Otkrytaya oboronka," *Stimul*, 8 June 2018.
[25] Pravitelstvo Rossii, "Oboronno-promyshlennyi kompleks."
[26] Ibid. The 65 vertically integrated structures in the defence industry are responsible for 80 per cent of production.
[27] On Rostec, see www.rostec.ru/about/.
[28] Tecmash, "Karta predpriyatii: Organizatsii pryamogo upravleniya Tekhmasha," (www.tecmash.ru/o-kontserne/spisok-predpriyatiy/).

Figure 1: Vertical integration in artillery ammunition and special chemicals



Even if the defence industry has undergone organisational changes as part of its adaptation to a new environment since the 1990s, "[t]he current sectoral organisation essentially reflects a managed economy with minor market elements."[29] The system is top-down controlled and primarily government-funded. Indeed, to a certain extent, state holdings have replaced the various Soviet ministries in coordinating innovation activities as well as controlling research institutes and design bureaus.[30] Notable examples are United Aircraft Corporation, for R&D on fixed-wing airplanes; United Shipbuilding Corporation, for submarines, corvettes, frigates and aircraft carriers; *Almaz-Antey*, for air defence systems; *Uralvagonzavod*, for main battle tanks; Tactical Missiles Corporation (*Korporatsiya Takticheskoe Raketnoe Vooruzhenie*), for air- and naval-based missiles; and the *Kalashnikov* concern, for a wide range of military weapons.

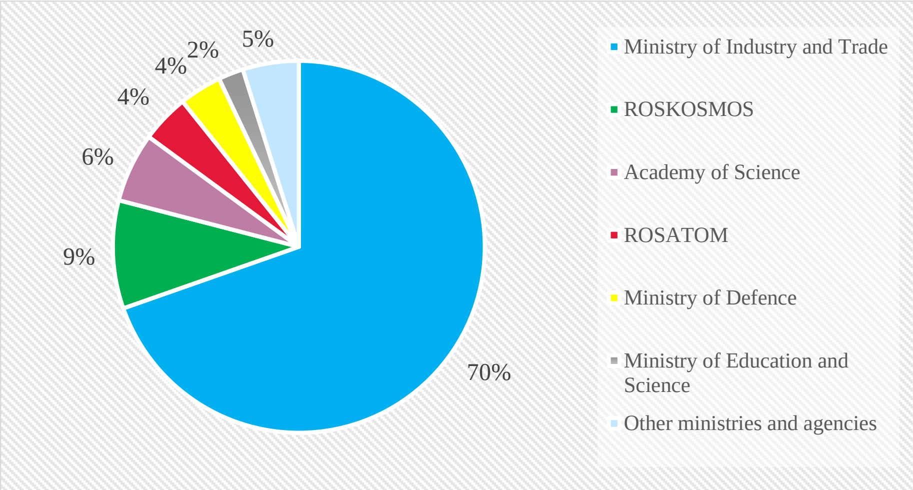
These R&D institutes and enterprises have different organisational and legal forms. Almost all of the organisations are federal state unitary enterprises, joint-stock companies (open or closed), or state institutions. The various R&D organisations are also overseen by specific ministries and agencies. MIT oversees the bulk of R&D, including all institutes in the branches of aviation, shipbuilding, conventional arms, ammunition and special chemicals, and radio electronics and communication systems. *Roscosmos* oversees the cosmonautics programmes and

[29] Malmlöf and Engvall, "Russian armament deliveries", p. 116.

[30] There were nine ministries that specialised in military R&D and manufacturing: the Ministry of Defence Industry (mainly tanks and armoured vehicles); the Ministry of the Aviation Industry (aircraft), the Ministry of the Communications Equipment Industry (communications equipment), the Ministry of the Electronics Industry (electronic components), the Ministry of General Machine Building (ballistic missiles and space technology), the Ministry of the Machine Tool and Tool-Building Industry (chemicals), the Ministry of Medium Machine Building (nuclear weapons), the Ministry of the Radio Industry (military radio and radar systems) and the Ministry of the Shipbuilding Industry (ships). See Cooper, *The Soviet Defence Industry*, pp. 6-11; Stephen Fortescue, *Science Policy in the Soviet Union*, London and New York: Routledge, 1990, pp. 80-81.

aerospace research. *Rosatom* comprises all R&D organisations in the nuclear energy industry. The Ministry of Defence (MoD) and the Ministry of Education and Science both have their own set of research institutes and design bureaus. The Russian Academy of Sciences (RAS) has 38 research institutes that are part of the defence industry, in 15 different cities and towns. The approximately 5 per cent of remaining R&D organisations belong to other federal agencies and ministries.[31] Figure 2 shows the percentage of defence-related R&D organisations overseen by various state institutions.

Figure 2: Distribution of R&D organisations across state institutions (in %)[32]



2.3 R&D organisations

The basic organisational contours of Russia's contemporary defence industry have strong historical roots, dating back to Stalin's time. The defence industry consists of a three-part chain, which includes research institutes, design bureaus and factories.[33] It is the two first parts in this chain – research institutes and design bureaus – that are of interest in this study. While research institutes primarily conduct applied research for the defence industry, design bureaus engage in

[31] These are the Federal Service for Technical and Export Control of Russia (FSTEK), the Federal Security Service (FSB), the Federal Agency for Technical Regulation and Metrology (Rosstandart), the Federal Medical-Biological Agency (FMBA), the Ministry of Digital Development, Communications and Mass Media and the Federal Communications Agency (Rossvyaz). See MIT, "Ob utverzhdenii perechnia organizatsii".

[32] Author's calculations based on database created from MITs defence industry register.

[33] Brian Harvey, *The Rebirth of the Russian Space Program*, New York: Springer, 2007, p. 265.

developing prototypes. There is also a third type of organisation with a role in military R&D, the scientific production association, which combines its R&D facilities with its own production capacity. Most R&D entities are large enterprises employing several hundred or more people. In contrast, there are few small enterprises and relatively few medium-sized enterprises. Of the defence industry's total output, about 30 per cent are scientific and technological products.[34]

2.3.1 Research institutes (NII)

Ideas and concepts for military applications are developed and tested in scientific research institutes (*nauchno-issledovatelskie instituty, NII*). Of the defence industry's approximately 1350 organisations, about 300 are research institutes, equivalent to more than 20 per cent of all organisations. More than half of these institutes are located in Moscow and smaller science towns just outside the capital.

The institutes vary in size depending on branch and functions. In the nuclear industry, the two major institutes are the All-Russian Scientific Research Institute of Experimental Physics, in the closed city of Sarov, Nizhny Novgorod oblast; and the All-Russian Scientific Research Institute of Technical Physics, in the closed city of Snezhinsk, in Chelyabinsk oblast. The institute in Sarov employs approximately 20,000, while the institute in Snezhinsk has a staff of around 12,000. The staff of other major research establishments appears to be in the range of 2000-4000. For example, the State Scientific Research Institute of Aviation Systems (*GosNIIAS*) has about 2000 employees, the Krylov State Research Centre, in St. Petersburg, has a staff of around 3000, and the Central Research Institute of Machine Building (*TsNIIMash*) employs approximately 3700 people.

In the 1990s and early 2000s, these institutes stagnated as a source of technological innovation. There were several reasons for this. The general economic downturn and dwindling state spending on R&D played a part. So did the extensive scientific brain drain, due to the emigration of scientists, an ageing cohort of scientists and poor supply of research talent from below. Indeed, rebuilding human capital was arguably one of the greatest challenges when the tide turned and the government started re-investing in military R&D. For example, research on the allocation of talent in Russia has shown that, on average, the best-performing students enrol in law programmes rather than cutting-edge engineering disciplines.[35]

During the past decade, however, the situation has improved overall in terms of pay and working conditions. There has also been a stronger focus on reviving technical engineering sciences. As a result, the average age of specialists and

[34] Evgeny M. Gunkin, "Sovremennoe sostoyanie Rossiiskogo oboronno promyshlennogo kompleksa i osobennosti ego funktsionirovaniya," *Izvestiya TulGU*, no. 2-1 (2018).

[35] Michael Alexeev, Timur Natkhov and Leonid Polishchuk, "Institutions and the Allocation of Talent: Evidence from Russian Regions," undated. For an insider view on the challenges of attracting young talents to defence R&D in the early 2010s, see *RIA Novosti*, "Genkonstruktor sistem REB: tekhnologii inogda tianut nas nazad," 27 June 2013.

scientists in the defence industry has decreased during the last several years. In particular, the growing number of scientists between 30 and 40 years of age should provide a reasonable base for the future.[36] At the same time, there is a shortage of scientists in ages between 40 and 59. For Russia, this appears to be something of a lost, post-Soviet, research generation.[37]

2.3.2 Design bureaus (KB)

The design bureau (*konstruktorskoe byuro, KB*) or experimental design bureau (*opytno-konstruktorskoe byuro, OKB*) was the central industrial organisation involved in the development of new technology for the Soviet defence industry. Its main purpose was to utilise the findings from research projects conducted in research institutes for designing and developing prototypes. Once perfected in the design bureau, prototypes were assigned to factories for mass production. In practice, however, the process was often more complex. While design bureaus often had affiliated factories, it was not uncommon that a design product of a particular bureau could be sent for production in a factory aligned with a rival design bureau. This lead to inbuilt competitive rivalries in the system.[38] For example, the development of jet fighters was a running competition between the two major aerospace design bureaus in Moscow – *Sukhoi* and *MiG* – but virtually all the production plants for fighters were located in faraway regions, sheltered from foreign enemies from the West.[39]

The design bureau remains a central institution for defence innovation in contemporary Russia. However, today, they are commercial organisations, or contractors, tasked with developing specific engineering projects for military purposes. The continuity with the past is evident from the fact that many prominent design bureaus retain the names of leading Soviet-era designers (*konstruktory*).[40] The contemporary defence industry counts just under 130 design bureaus among its organisations, which is equivalent to 10 per cent of all the entities. The highest number of design bureaus, approximately 37, are found in the aviation branch, but a strong presence is also seen in shipbuilding, rocket technology and conventional arms production. As expected, design bureaus are geographically concentrated in the Moscow and St. Petersburg areas, which account for one-third and 15 per cent of all bureaus, respectively. Other centres for design bureaus working on military applications are Nizhny Novgorod (9), Voronezh (6), Kazan (4) and Omsk (4). In

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[36] Gunkin, "Sovremennoe sostoyanie Rossiiskogo oboronno promyshlennogo kompleksa."

[37] Irina Dezhina and Sergei Egerev, "Skolko zhe uchenykh v sovremennoi Rossii i na chto oni sposobny. Kadry nauki vo tsvete let," *Nezavisimaya Gazeta*, 7 April 2020.

[38] Harvey, *The Rebirth of the Russian Space Program*, p. 265.

[39] Wallin, *The Post-Soviet Military-Industrial Complex*, p. 16.

[40] In the aerospace industry, premier design bureaus named after legendary designers include Sukhoi, Beriev, Korolev, Ilyushin, Mikoyan-Gurevich (MiG) and others.

addition to these independent design bureaus, several so-called scientific production associations (see below) have their own semi-independent design offices attached to their organisational structure.

2.3.3 Scientific production associations (NPO)

The scientific production association (*nauchno-proizvodstvennoe obedinenie*), a form of scientific research-to-production facility, had already emerged during the 1960s as the earliest and most widespread attempt to bridge the gap in the Soviet system between the R&D phase and the production phase. The defence industry as a whole was often characterised by delays stemming from bureaucratic barriers or a lack of technical capabilities to turn prototypes developed by design bureaus into serial production in factories. The purpose of the NPOs was thus to integrate the whole line of work from R&D to industrial production within a single administrative entity.[41]

In the post-Soviet period, several of the famous Soviet design bureaus and their affiliated production sites have been transformed into scientific production associations.[42] Nonetheless, the term design bureau remains widely used both in common parlance and in the institutes' formal names, which at times makes it difficult to draw the line between the two types of R&D organisations.[43] As a rule, the structure of the scientific production association includes research, design and engineering, pilot production and industrial enterprises.

Overall, there are approximately 170 scientific production associations in the Russian defence industry. The size of individual NPOs varies substantially. There are huge corporations, such as *Uralvagonzavod* – the world's largest manufacturer of main battle tanks – with an estimated 30,000-strong staff. However, in reality, this scientific production corporation is a gigantic holding firm under the umbrella of the super-holding concern, *Rostec*. *Uralvagonzavod's* subsidiaries include 15 manufacturing sites, seven research institutes, five design bureaus, four logistics and supply centres and six repair plants. Thus, only parts of the corporation's employees are involved in R&D.

Two of Russia's most prolific scientific production associations – *Energiya* and *NPO Mashinostroeniya* – develop a full range of rocket and space technology. As

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[41] Simon Kassel, *Soviet Advanced Technologies in the Era of Restructuring*, Santa Monica, CA: RAND, 1989, p. 51.

[42] While scientific production association is the most commonly used name, they also go under several other names, including scientific production enterprise (*nauchno-proizvodstvennoe predpriyatie*), scientific production corporation (*nauchno-proizvodstvennaya korporatsiya*,), scientific production complex (*nauchno-proizvodstvennyi kompleks*), scientific production centre (*nauchno-proizvodstvennyi tsentr*) and scientific production firm (*nauchno-proizvodstvennaya firma*). In this report, scientific production association is used for all of these integrated R&D and production organisations.

[43] In practice, this might mean that even more design bureaus could have evolved into scientific production associations. Thus, there is a possibility that the present study under-reports the number of scientific production associations, while over-reporting the number of design bureaus.

of 2019, *NPO Mashinostoeniya's* had 4350 employees, with more than 400 vacancies.[44] According to its official information, *Energiya's* staff includes more than 200 scientists with at least a doctor's degree. As of 2017, *Energiya* had a staff of 7791.[45]

Geographically, more than 40 per cent of the scientific production associations are located in the Moscow region and 15 per cent in St. Petersburg. Smaller clusters exist, for example, in Nizhny Novgorod, Rostov-on-Don, Kazan and Saratov. Their share of the total number of R&D organisations is particularly noteworthy in space technology (close to 50 per cent), ammunition and special chemicals (roughly 40 per cent), and aviation (almost 40 per cent).

2.4 Geographical concentration

Geographically, R&D organisations are largely concentrated in scientific industrial complexes, which combine scientific research and production. Nearly half of Russia's R&D facilities are located in and around Moscow and almost one-fifth in St. Petersburg. In addition, smaller clusters are found in cities and some towns in central and northwest Russia, such as Tula, Vladimir and Yaroslavl oblasts. The large cities along the Volga river – especially Nizhny Novgorod, Kazan and Samara – constitute another military R&D belt. Then, there is the area of the south and southwest Urals – with Yekaterinburg, Chelyabinsk and Perm as examples. Finally, the cities along the trans-Siberian railway – Omsk, Novosibirsk, Tomsk, Krasnoyarsk and Irkutsk – also retain some defence-related R&D organisations. However, the defence industry no longer forms the basis of these cities in the way it used to during Soviet times.

This territorial characteristic is a consequence of the need for highly qualified personnel and advantageous physical infrastructure and communications, which urban centres, particularly west of the Urals, provide for.[46] Historical legacies from the Soviet Union, such as the concentration of the defence industry in general and defence R&D in particular in certain science cities (*naukogrady*), likewise have a lingering impact on the geographical distribution of R&D organisations. A map of the geographical distribution of military R&D entities is presented below.

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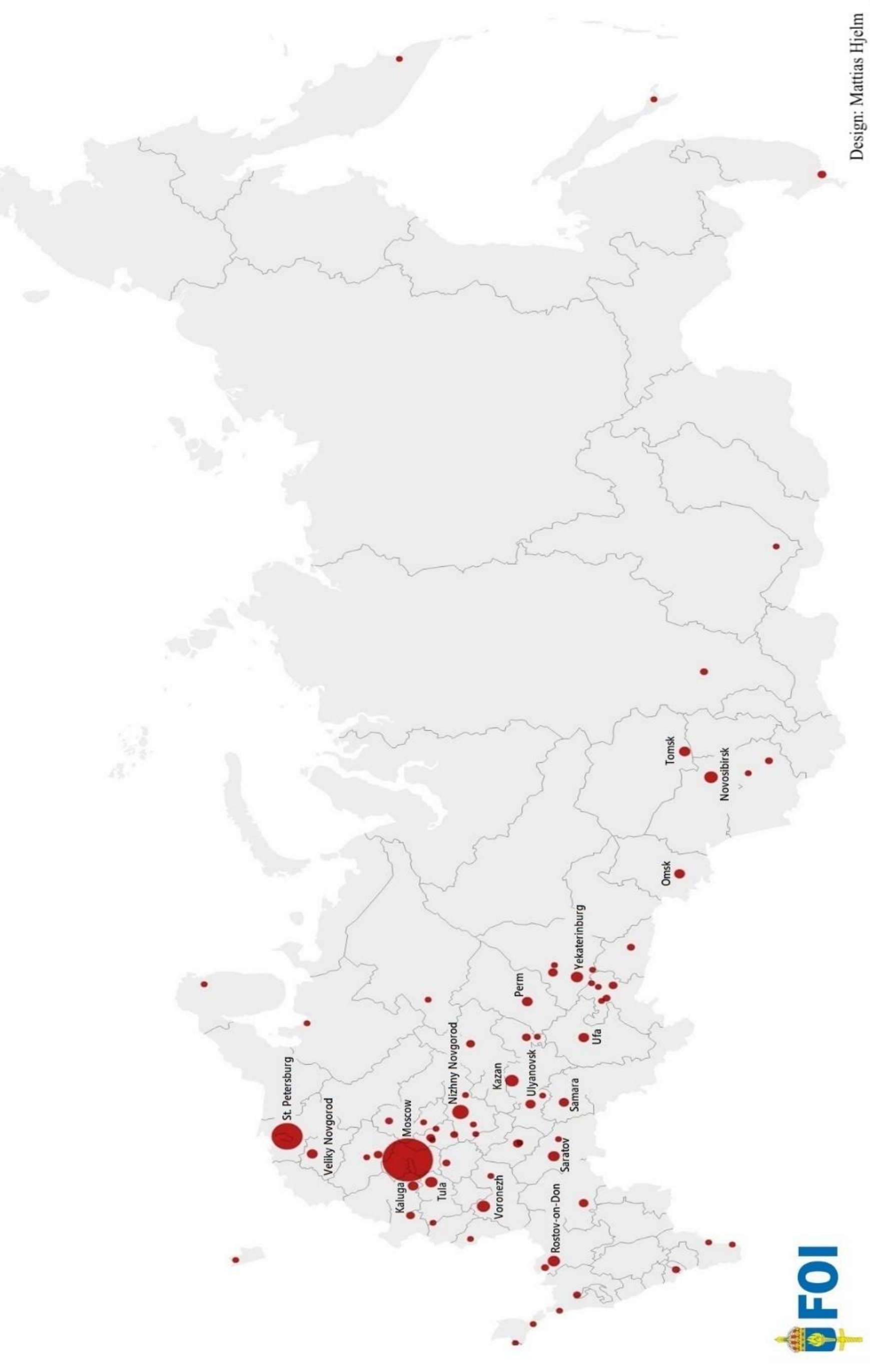
[44] Nina Borisenko, "Sostoyalsya ocherednoi den kadrov," NPO Mashinostroeniya, press report, 13 March 2019.
[45] "Poyasneniya k bukhgalterskoi (finansovoi) otchestnosti za 2017 god PAOPKK 'Energiya'," p. 6.
[46] Gunkin, "Sovremennoe sostoyanie Rossiiskogo oboronno promyshlennogo kompleksa."



Map: Geographical concentration of military R&D entities

2.5 Seven major branches

Breaking down the approximately 600 R&D entities into branches allows us to visualise the different components of the R&D infrastructure as well as provides clues regarding prioritised areas. Russia's military R&D can be divided into seven main branches: aviation; space technology; shipbuilding; conventional arms; radio, electronics and communication systems;[47] ammunition and special chemicals; and nuclear energy and weapons.[48] That said, the activities of several organisations cut across branches. For example, *KB Mashinostroeniya*, a leading designer of torpedo tubes for surface ships and electronic warfare systems for ships, falls in the category of shipbuilding, while simultaneously being heavily involved in R&D associated with radio electronics and communication systems. Table 3 summarises the distribution of R&D organisations across industrial branches.

Table 3: Number of R&D organisations across defence industry branches[49]

Branches of defence industry	Research institutes	Design bureaus	Scientific production associations	R&D entities in total
Aviation	20	37	33	**90**
Space technology	19	10	27	**56**
Electronics	23	6	17	**46**
Radio	43	19	29	**91**
Communications	28	6	17	**51**
Shipbuilding	12	16	7	**35**
Ammunition & special chemicals	17	1	13	**31**
Conventional arms	17	13	12	**42**
Nuclear technology	20	2	3	**25**
Others	100	18	10	**128**
Total	299	128	168	**595**

[47] This branch represents the author's merging of the three 'sub-branches' of radio, electronics and communication systems. In Table 3, however, they are shown separately.
[48] While there are also other branches, some of them are not primarily preoccupied with defence systems research and engineering.
[49] Author's calculations based on database created from MITs defence industry register.

In the following, these seven major branches are specified in detail by looking at their line of work and their territorial clusters.

Aviation: Research institutes, design bureaus and scientific production associations active in the aviation sector work on developing aircraft and helicopters of all types, as well as unmanned aerial vehicles (UAVs) and airfield equipment. The major R&D clusters are located in Moscow and surrounding satellite towns, in particular Zhukovsky. Other notable R&D centres are Kazan, Nizhny Novgorod and Ufa, in Bashkortostan. Overall, half of the research R&D infrastructure is located in Moscow and Moscow oblast. Of the scientific research institutes alone, no less than 75 per cent are situated in Moscow.

Shipbuilding: R&D facilities in the shipbuilding industry engage in developing all types of surface ships and vessels, as well as nuclear and diesel electric submarines, for the navy. An increasing amount of R&D work is likewise undertaken in designing unmanned underwater and surface vehicles. St. Petersburg is Russia's prime centre for shipbuilding R&D. Additional research facilities are primarily located in Moscow. Meanwhile, there are several design bureaus in Nizhny Novgorod, located at the confluence of the Volga and Oka rivers, in central Russia.

Space and rocket technology: Various R&D organisations lead activities to develop spacecraft, carrier rockets, artificial satellites and ground infrastructure for spaceports. R&D for the rocket and space industry mainly takes place in the Moscow region. St. Petersburg, Voronezh and the Chelyabinsk oblast all have their own R&D clusters.

Radio electronics and communication systems: R&D enterprises belonging to this broad branch include three sub-branches: radio, electronics and communication systems. These sub-branches are all concerned with electronics-related activities. This is a truly cross-cutting branch as several companies falling under other categories also conduct R&D related to radio, electronics and communications. Moreover, R&D in several new technology areas, such as artificial intelligence (AI) and military automation are found in this branch as well as others.[50]

In the electronics sector, R&D efforts cover electronic components, computing technology, microprocessors and many other things. By the 1980s, it was already widely known that the Soviet Union's electronics industry had slipped significantly behind the West's. The collapse of the Soviet system had an adverse impact on an already crumbling sector, since many R&D centres were located outside Russia's borders, in Latvia, Lithuania, Belarus and Ukraine.[51] To compensate for inadequate domestic supply, electronics components for weapons were imported

[50] AI and military automation as examples of cross-engineering areas are analysed in Chapter 3.

[51] These included the Design Bureau for Precision Electronic Machine Building, in Minsk, the Vilnius Design Bureau, the Machine Building and Tool Plant, with its associated Special Design Bureau, in Riga, and an institute in Kyiv. See Central Intelligence Agency (CIA), *The Soviet Microelectronics Industry: Hitting a Technology Barrier*, CIA Special Collections Release as Sanitized, 2000.

from abroad. However, since the introduction of Western and Ukrainian sanctions against Russia in 2014, import substitution measures were undertaken in order to avoid external dependencies. However, according to many experts, the electronics industry and related sub-fields remain an Achilles heel in Russian efforts to compete, especially in future-oriented military technologies.[52] The major Russian R&D sites in electronics are Moscow and its satellite town, Zelenograd, which since Soviet times has been the closest Russia has come to having an equivalent to Silicon Valley.

In the traditionally prestigious Russian radio industry, R&D organisations work for example on the creation of military radios, radar systems, anti-aircraft and anti-missile systems, computers, and control and navigation systems. The companies specialising in R&D for the radio industry are heavily concentrated in Moscow and St. Petersburg.

The communications sphere is closely linked to radio and electronics and includes a range of R&D activities in information and communication technology. Organisations are evenly spread between Moscow and St Petersburg. In addition, Voronezh, Veliky Novgorod, Nizhny Novgorod and Mytishchi, in the outskirts of Moscow, also host a few R&D organisations in this field.

Ammunition and special chemicals: In this field, R&D organisations develop all sorts of ammunition, gunpowder, rocket fuel and chemical weapons. The work is primarily concentrated in Moscow and the wider Moscow area, but additional research clusters exist in Dzerzhinsk, in Nizhny Novgorod oblast (for the chemical industry), as well as Tula and Novosibirsk.

Conventional arms: In this sector, R&D covers a broad span of armaments, including armoured vehicles, artillery systems, small arms and air defence systems. Here, research and innovation facilities spread more evenly than in most other sectors; however, there is again a certain concentration in Moscow and St. Petersburg. Tula and the Vladimir region also host several R&D organisations. Another notable centre is Nizhny Tagil, the second largest city in Sverdlovsk oblast. The city is home to *Uralvagonzavod,* one of the country's largest scientific and industrial complexes.

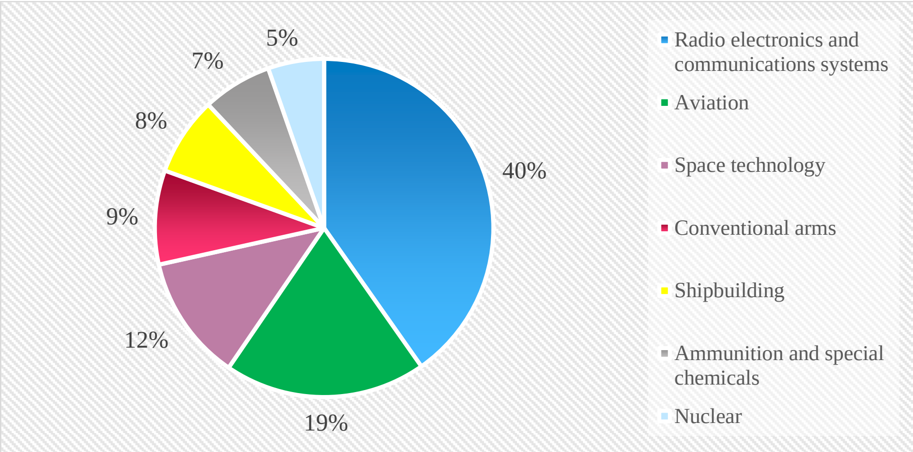
Nuclear technology: In the nuclear industry, R&D entities deal with nuclear power plants, nuclear warheads, control equipment and various protection measures. R&D efforts in the field are concentrated in the Moscow region, with a smaller concentration of facilities elsewhere, primarily in Nizhny Novgorod and St. Petersburg. The internationally renowned *Kurchatov Institute,* in Moscow, is Russia's leading civilian R&D institution in the field of nuclear energy. The two major research institutes working on nuclear technology for Russia's armed forces are the All-Russian Scientific Research Institute of Technical Physics and the All-

[52] See for example Dear, "Will Russia Rule the World Through AI?"

Russian Scientific Research Institute of Experimental Physics. They are located in the closed towns of Snezhinsk in Chelyabinsk oblast and Sarov in Nizhny Novgorod oblast, respectively. The *Afrikantov Experimental Design Bureau for Mechanical Engineering* in Nizhny Novgorod is the main developer of small power reactors, fast breeder reactors, and reactors for naval propulsion and heat generation.

To summarise the discussion above, Figure 3 visualises the share of R&D organisations of each industrial sector.

Figure 3: Distribution of R&D organisations across branches (in %)[53]



The division of the defence industry into specific branches should not detract, however, from the fact that many complex weapons systems integrate several branches. Take, for example, the struggle to introduce the fifth-generation stealth fighter, Su-57, which the Sukhoi Design Bureau started developing in 2002. The first Russian aircraft based on stealth technology, this advanced system integrates many complex sub-systems developed by R&D establishments that do not formally belong to the aviation industry. To illustrate, the basis of the Su-57's advanced electronics system is an all-new dual-band N036 radar system, developed by the V. Tikhomirov Scientific Research Institute of Instrument Design. Apart from the main radar system, the aircraft will have a set of other active and passive radars installed across its entire surface. The aircraft is also expected to feature the L402 Himalay Electronic Warfare (EW) system, developed by the KNIRTI EW Research Institute of Kaluga.[54] The Su-57 is furthermore

[53] Author's calculations based on database created from MITs defence industry register.
[54] Alexander Mladenov, "T-50 Mission Avionics Suite," *Moscow Defense Brief*, no. 2 (2017): 6.

equipped with the S-111-N integrated communications system, developed by the NPP Polyot of Nizhny Novgorod.[55] The engine is supposed to be a heavily upgraded design, from NPO Saturn.[56] Vympel, a scientific production company specialising in air-to-air missiles, is responsible for developing new advanced missiles for the aircraft.[57]

To sum up, in the 1990s, the withdrawal of state subsidiaries and dwindling of state orders undoubtedly put the military R&D organisations under great stress. Nonetheless, the vast majority of R&D entities managed to muddle through. Thus, when state spending and demand for military systems returned, following the ambitious GPV-20 in 2010, the general infrastructure remained more or less intact.[58] In other words, while the neglect of the 1990s resulted in the need for investments in equipment and infrastructure, it was by no means the case of building-up the R&D industry from scratch. The increased state focus on overall armament modernisation and new technologies have put Russia's military R&D in a significantly better place than it was a decade ago. Its competitiveness remains particularly strong in aviation, nuclear technology and space exploration, while the electronics branch continues to lag behind internationally.[59] The breadth of branches and competencies within the military R&D structure is illustrated in Table 4.

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[55] Mladenov, "T-50 Mission Avionics Suite," p. 7.

[56] Dylan Malyasov, "Russia Revealed New Engine Developed to Power Fifth Generation Aircraft," *Defence Blog,* 20 October 2017.

[57] *Military Watch Magazine,* "A Firepower Boost for the Su-57: Several New Missiles Developed to Equip Russia's Next Generation Fighter," 9 October 2020. Note that NPO Vympel is not related to the Vympel design bureau, which is involved in shipbuilding.

[58] See Jonas Kjellén, *Russian Electronic Warfare: The Role of Electronic Warfare in the Russian Armed Forces,* Stockholm: Swedish Defence Research Agency – FOI, September 2018.

[59] Aviation, nuclear technology and space exploration remained competitive even in the troubled 1990s and early 2000s, while the electronics sector has been falling behind since at least the 1980s; see Roffey, "Russian Science and Technology," pp. 162-188.

Table 4: Major R&D organisations across branches[60]

Branches	NII	KB	NPO
Aviation	**GosNIIAS**: aviation weapons systems. **All-Russian Scientific Research Institute of Aviation Materials (VIAM)**: materials used in aircraft and space vehicles.	**Sukhoi**; military aircraft, UAVs. **Novator**: long-range anti-aircraft missiles. **Kamov**: attack and transport helicopters.	**Molniya**: reusable launch systems, aircraft. **Klimov**: aircraft engines.
Space technology	**TsNIIMash**: long-range ballistic missiles and air defence missiles. **Moscow Institute of Thermal Technology**: ballistic missiles, launch vehicles.	**Makeyev**: missile design. **Fakel**: electric propulsion systems.	**Energomash**: rocket engines. **Energiya**: ballistic missiles, spacecraft.
Radio electronics & communication systems	**Moscow Radiotechnical Institute**: microwave technology. **Research Institute of Molecular Electronics (NIIME)**: technologies for microelectronics. **ETALON**: traditional and modern communication systems.	**Kompas**: radio navigation support. **Milandr**: electronic equipment.	**Toriy**: microwave tubes for radars, communications systems and nuclear reactors. **KVANT**: avionics systems. **INTELTECH**: automated communication systems.
Shipbuilding	**Krylov State Research Centre**: one of the world's largest research centres in shipbuilding.	**Rubin**: submarine design. **Vympel**: designer of ships and other vessels.	**Avrora**: automated control systems for the navy.
Ammunition and special chemicals	**State Research Institute Kristall**: explosives and special chemicals. **Snegirev Research Technological Institute**: explosive devices.	**Central Design Bureau of Polymer Materials**: development of new polymer materials.	**SPLAV**: rocket launch systems. **Bazalt**: bombs, RPG, anti-tank weapons.
Conventional arms	**Vavilov State Optical Institute:** optical systems for military application.	**Titan Central Design Bureau**: artillery, ballistic missile launchers.	**Uralvagonzavod**: MBTs, military vehicles, unmanned platforms.
Nuclear technology	**All-Russian Scientific Research Institute of Technical Physics**: R&D centre for nuclear weapons.	**Afrikantov**: designer of reactors for nuclear submarines.	**Krasnaya Zvezda**: nuclear power systems for spacecraft.

[60] Author's compilation based on database created from MITs defence industry register.

3 Cross-cutting critical military technologies

Several prominent experts argue that new scientific and technological breakthroughs are necessary for taking Russia's military capabilities into the emerging era of autonomous military systems.[61] It is increasingly common to talk about a seventh military revolution – the autonomous revolution – at the core of which is the combination of machines and computers.[62] Autonomous weapons, swarms of robotic vehicles in multiple domains, self-organising defensive systems, automated weapons, big data analytics and machine- and deep-learning programmes are at the heart of a potential far-reaching alteration of how future wars will be conducted.[63]

However, in an international perspective, Russia has lagged behind Western countries in high-technology innovations over the past decades. The stock of knowledge carried over from Soviet times is coming to an end as a source of new developments. This is especially obvious when comparing the State Armament Programme 2011-2020 (GPV-2020) with its successor programme, GPV-2027. If defence deliveries in the former focussed on renewing the development of a number of Soviet projects initiated in the 1980s, but mothballed after the collapse of the Soviet Union, the latter places greater emphasis on the future transformation of Russia's military capabilities. Thus, GPV-2027 devotes a stronger commitment to basic and exploratory research in order to ensure that Russia is not dependent on other countries regarding militarily critical technologies.[64]

Moreover, in recent years, President Putin has repeatedly emphasised the need for Russia to achieve breakthroughs in high technology areas.[65] In particular, Russia has devoted strong attention to the fields of AI and automation, with a particular focus on the implications for future military use. In the attempts to develop a new

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[61] See for example Richard Connolly and Mathieu Boulègue, *Russia's New State Armament Programme – Implications for the Russian Armed Forces and Military Capability to 2027*, London: Chatham House, May 2018, p. 32.

[62] The previous revolutions refer to 1) the Westphalian System, and the emergence of professional militaries; 2) the French Revolution, of conscript-based mass armies; 3) the Industrial Revolution, of mass production and standardisation of defence production; 4) World Wars I & II, and the introduction of combined arms and carriers, bombers and jets; 5) the Nuclear Revolution, and missiles, which introduced nuclear weapons and intercontinental ballistic missiles; 6) the Information Revolution, with command and control and instant global reach; see F. G. Hoffman, "Will War's Nature Change in the Seventh Military Revolution?" *Parameters*, vol. 47, no. 4 (2017-18): 20.

[63] Hoffman, "Will War's Nature Change?" p. 20; NATO Science & Technology Board, *Science & Technology Trends 2020-2040*, NATO unclassified, releasable to Australia, Finland and Sweden, 31 March 2020.

[64] See for example Julian Cooper, "The Russian State Armament Programme, 2018 – 2027," *NATO Defense College*, May 2018, p. 13.

[65] See for example President of the Russian Federation, "Poslanie Prezidenta Federalnomu Sobraniyu," 15 January 2020.

generation of weapons, the implicit, if not always explicit aim is to catch up with the West in critical military technologies. This raises the question of how Russia is funding and organising R&D initiatives in order to be competitive in these fields.

The government has made some investments in strengthening basic high-risk research aimed at developing new high-technology products for the armed forces.[66] In 2012, the government established *Fond Perspektivnykh Issledovanii* (FPI). FPI's projects are supposed to take a lead role in the development of a new generation of weapons, and provide the basis for the Russian armament system for the period 2025-2030.[67] Roughly modelled on the US Defense Advanced Research Projects Agency (DARPA), the foundation funds and supports research projects in areas such as robotics, nanotechnology and intelligent weapons. For its first five years of work, 2013-2017, the FPI received 18.2 billion roubles from the federal budget. However, in real terms, the funding in 2017, of 3.4 billion roubles, was almost 45 per cent lower than in 2013, representing a reduction from 2 per cent of national defence expenditures in 2013 to 1 per cent in 2017. Thus, although the FPI is increasingly held up as a key institution for advancing Russian military technology in the coming ten years, its annual budget equivalent of approximately 60-70 million dollars can be compared to the nearly 3 billion dollars managed by DARPA.[68] Accordingly, Russia seems forced to concentrate its high-risk research efforts to a few selected areas.

A review of the FPI's first five years of work concluded that while the foundation funds and supports several promising research projects, there was little open information available indicating whether the research had led to any useful result for military application.[69] Since then, the foundation has introduced a website presenting various ongoing projects for military use, including a high-speed aircraft engine, an experimental robotic platform, an ultra-deep diving complex, a reusable rocket and space system, the first Russian atmospheric satellite, and several others.[70] For ground-based robotics, FPI aims to increase the level of autonomy of the systems.

In comparison with the previously documented traditional defence industrial branches, research on new technologies includes a stronger relationship between civilian and military research. In 2019, FPI concluded an agreement with the Ministry of Science and Higher Education to cooperate in breakthrough areas of

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[66] Aleksey Nikolsky, "Finansirovanie oboronnykh nauchno-issledovatelskikh rabot uvelichitsya," *Vedomosti* 21 May 2017.

[67] *Izvestiya,* "Proekty FPI stanut osnovoi otechestvennoi sistemy vooruzhennïi," 19 January, 2016.

[68] See Aleksey Nikolsky, "Advanced Research Foundation: Five Years of Secret Efforts," *Moscow Defense Brief,* no. 3 (2018): 7-8; Jacques Knight, "DARPA, the F-35, and the Return of Russia," *Digital Transformation*, 6 September 2018.

[69] Nikolsky, "Advanced Research Foundation," pp. 7-8.

[70] See the Fond Perspektivnykh Issledovanii (FPI) official website's section on research projects, www.fpi.gov.ru/projects/fiziko-tekhnicheskie-issledovaniya/.

research for military applications.[71] With regard to future-oriented critical military technologies, the government has also instructed RAS – still the country's premier institution for basic research – to play a leading role. That said, in comparison to R&D in the US, with its close relationship between industry and universities, Russia's military R&D has weak ties to both higher educational institutions and civilian industry.[72]

3.1 Artificial intelligence

> Artificial intelligence (AI) refers to the ability of machines to perform tasks that normally require human intelligence – for example recognizing patterns, learning from experience, drawing conclusions, making predictions, or taking action – whether digitally or as smart software behind autonomous physical systems.[73]

There has been much buzz around Russia's efforts in the field of AI, ever since President Putin stressed, in 2017, that the one who becomes the leader in this sphere will become the ruler of the world.[74] Russia's push in this area, however, is primarily driven by a perceived need to catch up with its leaders, such as the US and China.[75] In October 2019, the Russian government rolled out a national strategy, until 2030, for the development of AI.[76] In turn, the government inserted a deferral project into the national programme for the Digital Economy of the Russian Federation, with a funding of up to 90 billion roubles ($1.4 billion) for six years.[77] In comparison to other countries, Russia's approach to AI is tightly state-controlled, from financing to the organisation of R&D. Under its national programme for digital economy, public funds are allocated to various state-controlled companies charged with leading the development of AI. In contrast, the private sector is not entrusted to play a significant role in the drive to develop AI.[78]

As a result of the state-centred approach, military AI plays a strong role in Russia, reflecting the leadership's prioritisation of defence and security.[79] The MoD is responsible for the development of military AI and foresees research in three major

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[71] *TASS*, "Minobranuki i FPI podpisali soglashenie o sotrudnichestvo po proryvnym razrabotkam," 9 July 2019.

[72] The need to strengthen the ties between military R&D and civilian R&D is acknowledged in President of the Russian Federation, *Strategy for Scientific and Technological Development of the Russian Federation*, Executive Order by the President of the Russian Federation, No. 642, 1 December 2016.

[73] NATO, *Science & Technology Trends 2020-2040*, p. 14.

[74] *TASS*, "Putin: lider po sozdaniyu iskusstvennogo intellekta stanet vlastelinom mira," 1 September 2017.

[75] Carolina Vendil Pallin, "Ryssland och AI: Målsättningar, centrala aktörer och konkurrenskraft," Underlag till Regeringskansliet, 3 December 2020.

[76] President of the Russian Federation, "O razvitii iskusstvennogo intellekta v Rossiiskoi Federatsii," Ukaz Prezidenta Rossiiskoi Federatsii, 10 October 2019. The strategy deals solely with the civilian sphere and does not reveal how the Russian government foresees R&D on military AI.

[77] Vadim Kozyulin, "Militarization of AI," in *The Militarization of Artificial Intelligence*, United Nations, August 2019, p. 25.

[78] Keith Dear, "Will Russia Rule the World Through AI?" p. 51.

[79] Ibid.

areas: creation of knowledge-based systems to enhance weapons, neural networks, and heuristic search systems for solving problems more quickly.[80] The MoD's Department for Research and Technological Support of Advanced Technologies is a central structure for specifying contracts related to AI and military autonomy. FPI is also taking an increasingly crucial role in funding, organising and researching military AI. FPI proposed a standardisation of applied AI research around four major areas: image recognition, speech recognition, management of autonomous military systems, and information support for weapons life cycles.[81]

President Putin envisions a lead role for the MoD's new military innovation complex, *Era*, in developing smart weapons equipped with AI-based systems.[82] *Era* – a technopark encompassing 17 hectares in the resort town of Anapa, along the Black Sea coast – is devoted solely to military research. It is reportedly equipped with an infrastructure that encompasses all stages in the R&D process, from basic exploratory research to the development of prototypes and testing of new weapons.[83] The idea is to provide an integrated complex for streamlining and accelerating R&D for simple and complex weaponry, in order to meet the demands of the modern era.[84] It officially opened in 2019 and the MoD expected it to be fully operational in 2020. Various research institutes belonging to the MoD as well as research institutes from RAS and representatives from Russia's major institutions for higher education have established a presence in the complex. In addition, several defence enterprises, such as *Kalashnikov*, *Sukhoi*, *Tupolev* and many others, were quick to set up their own laboratories and offices at the research campus, while others are expected to follow.[85]

For AI research, one of the cardinal priorities, *Era* includes 40 laboratories and other facilities, including a data processing centre for the benefit of the various R&D organisations working in the technopark.[86] A stated research priority is to create a quantum supercomputer.[87] *Era* is under military command, while its

[80] Samuel Bendett and Martijn Rasser, "Transcript from Russian Advances in Military Automation and AI," Center for a New American Security, 4 June 2020.

[81] *RIA Novosti*, "FPI predlozhil Minoborony RF sozdat standarty dlya iskussvennogo intellekta," 20 March 2018.

[82] Angelina Galanina, Dmitrii Lyudmirskii and Roman Kretsul, "Oruzhie razuma: rossiiskii put k voennomu iskusstvennomu intellektu," *Izvestiya*, 22 November 2018.

[83] Inna Sidorkova, "Tekhnopolis 'Era' dlya Shoigu vozvedut striteli BAMa," *RBC.ru*, 10 May 2018.

[84] Aleksandr Tikhonov, "Chtoby oruzhie budushchego sozdavat bystree," *Krasnaya zvezda*, 6 August 2018.

[85] Zakvasin and Komarova, "Novaya 'Era'."

[86] In total, *Era* organises its research in 14 prioritised directions: 1) AI technologies; 2) small spacecraft; 3) robotic systems; 4) information security; 5) automated-control systems and IT systems; 6) power supply technologies and life-support machines; 7) technical vision and pattern recognition; 8) informatics and computer engineering; 9) biotechnical systems and technologies; 10) nanotechnology and nanomaterials; 11) meteorological and geophysical support; 12) hydroacoustic object detection systems; 13) military geographic information platforms; and 14) weapons based on new physical principles. See the official website: Era, Pervyi voennyi innograd, www.era-tehnopolis.ru/.

[87] Aleksei Zakvasin and Elizaveta Komarova, "Novaya 'Era': kak Minobormy Rossii razvivaet unikalnyi voennyi tekhnopolis," *RT.com*, 16 April 2019.

scientific coordination council, in charge of selecting research projects, is led by Mikhail Kovalchuk, the president of the Kurchatov Institute.[88] The research projects undertaken at the complex are implemented both as individual initiatives and within the framework of the state defence order.

According to the industrial director of the giant *Rostec* conglomerate, major defence industrial contractors *Kalashnikov*, High Precision Systems and *Tecmash* have emerged as drivers of the development and production of AI systems, both for civilian and military needs.[89] For military applications, Russia's defence industry is working on AI for various unmanned systems, including combat robots and the deep-diving unmanned underwater vehicle Vityaz-D. It is also attempting to develop cruise missiles with AI components. In 2017, the CEO of Tactical Missiles Corporation, Boris Obnosov, noted that it will take years before most projects yield specific results. He also emphasised that this is a field where basic research is needed.[90] Additional concrete projects include using AI to develop 'smart mines' and AI-enabled EW systems. In the area of command and control (C2), the Russian military has already made significant advances in using AI to introduce and test enhanced automation in several C2 processes.[91]

Overall, Russia is relying on tested methods in organising AI research, which includes strong top-down state control, a central role for defence-related R&D and the continuation of the trend of concentrating R&D efforts in certain technology parks. In this state-managed R&D system, private sector initiatives and market demands play a subordinate role. For example, it is difficult not to see *Era* as inspired by the Soviet idea of concentrating military technology development in specific science cities. It remains to be seen whether *Era*'s location, far away from Russia's established R&D clusters, will hamper its innovation potential.

3.2 Autonomy and robotics

> *Autonomy* is the ability of a system to respond to uncertain situations by independently composing and selecting among different courses of action in order to accomplish goals based on knowledge and a contextual understanding of the world, itself, and the situation. Autonomy is characterised by degrees of self-directed behaviour (levels of autonomy) ranging from fully manual to fully autonomous . . . *Robotics* is the study of designing and building autonomous systems spanning all levels of autonomy (including full human control). *Unmanned Vehicles* may be remotely controlled by a person or may act autonomously

[88] Mikhail Kovalchuk is the older brother of Yuri Kovalchuk, who is the main shareholder of the 'Rossiya' bank, and who has a close relationship to President Putin.

[89] Sergey Sukhankin, "'Special Outsider': Russia Joins the Race for Global Leadership in Artificial Intelligence," *Eurasia Daily Monitor*, 13 March 2019.

[90] Dom Galeon, "Russia Is Building an AI-powered Missile That Can Think for Itself," *Business Insider*, 26 July 2017.

[91] Roger McDermott, "Moscow Showcases Breakthrough in Automated Command and Control," *Eurasia Daily Monitor*, 20 November 2019.

depending on the mission. Applications include access to *unreachable* areas, persistent surveillance, long-endurance, robots in support of soldiers, cheaper capabilities, and automated logistics deliveries.[92]

In the field of robotics and autonomous systems, sometimes referred to in Russia as "intelligent robotic complexes", the government set up a research and testing centre in 2013, as well as a commission to develop military robotics. In 2014, the government approved a programme for the development of advanced military robots by 2025, alongside a plan for the deployment of military robots by 2030.[93] The Military Industrial Commission has also set the ambitious target of making 30 per cent of Russia's military equipment robotic by 2025. Since 2015, FPI has been operating a National Centre for the Development of Technologies and Basic Elements of Robotics. At the Russian Academy of Military Sciences annual conference in March 2019, chief of the General Staff Valery Gerasimov stressed the role of military scientists in developing "digital technologies, robotics, unmanned systems, and electronic warfare."[94] This message confirms the priority given to the kind of basic research that the government expects FPI to fund, facilitate and lead in cooperation with RAS.

While Russia lagged significantly behind in unmanned platforms a decade ago, it is now catching up. The government's push in this area is manifested in a multitude of ongoing advanced development projects on a wide range of UAVs, but also unmanned underwater/surface vehicles (UUV/USV) and unmanned ground vehicles (UGV) for combat and combat support functions. For example, while the country possessed less than 200 UAVs a decade ago, that figure now stands at over 2000, and is replenished by 300 every year.[95] In 2020, it even trialled a 'swarm of reconnaissance drones' in the Kavkaz-2020 military exercise.[96] While swarm technology in Russia is commonly believed to be a long way behind that of the US and China, the Russian defence industry is nevertheless conducting R&D on the application of AI in UAVs, with the ambition of enabling them to perform as unified "swarms of drones" in combat zones.[97]

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[92] Italics in the original; see NATO, *Science & Technology Trends 2020-2040*, p. 16.

[93] Anton Lavrov, "Russian Military Terrestrial Robots," *Moscow Defense Brief*, no. 1 (2017): 13-15.

[94] Roger McDermott, "Gerasimov Unveils Russia's 'Strategy of Limited Actions'," *Eurasia Daily Monitor*, 6 March 2019.

[95] Ivan Petrov, "2019 goda v voiska nachnut postupat razvedyvatelno-udarnye bespilotniki," *Rossiiskaya Gazeta*, 18 December 2018; Roger McDermott, "Russia's Armed Forces Exploit Robotic Technology to Transform Operational Capability," *Eurasia Daily Monitor*, 19 June 2018.

[96] On Russian technology lag in this area, see Dear, "Will Russia Rule the World Through AI?", p. 51; David Hambling, "Russia Uses 'Swarm Of Drones' in Military Exercise For the First Time," *Forbes*, 24 September 2020.

[97] Jason Le Miere, "Russia Developing Autonomous 'Swarm of Drones' in New Arms Race With U.S., China," *Newsweek*, 15 May 2017.

3.2.1 In the air

During the past decade, Russia has been catching up on the development of UAVs, especially smaller tactical UAV reconnaissance systems. In addition, Russia has several development projects for combat UAV systems reportedly nearing completion. These projects include the long-endurance Altair, the medium-altitude long-endurance Orion, and the heavy, combat-UAV jet, S-70 Okhotnik. These projects seek to address Russia's lack of strike drones, a capability gap that has become increasingly obvious both in Syria and during the war between Armenia and Azerbaijan over Nagorno-Karabakh in autumn 2020. All three projects have been in development since 2011, but it remains highly unclear when they will actually enter service. Both Altair and Orion have had serious difficulties with their engine development. Initially, the projects used foreign engines, but following the annexation of Crimea and the imposition of sanctions, Russia has struggled badly to build its own power units for the drones.[98]

Okhotnik, in turn, is a long-distance strike UAV with a readily available engine, under development by the Sukhoi design bureau since 2011. Its origins date back to 2009, when Sukhoi and MiG worked jointly on a heavy, strike drone.[99] The Russian defence industry sees Okhotnik as a prototype for a sixth generation of Russian fighters.[100] The Okhotnik has a projected top speed of 1000 km/h and weighs up to 20 tonnes. The Okhotnik incorporates some technologies from the Su-57, but has also been delayed by a number of years.[101]

The first prototype was revealed in 2017; ground tests of the engine started in late 2018.[102] Its maiden, proper test flight took place in August 2019. In September 2019, Russia's Ministry of Defence released a video showing the Okhotnik flying alongside the Su-57, leading to speculation that both systems will be used together in certain combat situations.[103] According to the head of the United Aircraft Corporation, Yuri Slyusar, serial deliveries of Okhotnik, from the Novosibirsk Aviation Plant, should begin by 2024.[104]

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[98] According to some experts, it would have been preferable to build Russian engines from the start. See Valerii Butymov, "Razrabotchik dvigatelei dlya BPLA: otral spaset tolko tsentr kompetentsii pod krykom Minoborny," *MirTesen.ru*, 13 May 2020.

[99] Julian Cooper, "Russia's 'Invincible' Weapons: An Update," Changing Character of War Centre Pembroke College, University of Oxford With Axel and Margaret Ax:son Johnson Foundation, March 2019, p. 11.

[100] *TASS*, "Istochnik: tyazhelyi bespilotnik 'Okhotnik' na ispytaniyakh razognalsya na polose do 2000 km/ch," 23 November 2018.

[101] Cooper, "Russia's 'Invincible' Weapons," p. 11; Samuel Bendett, "The Rise of Russia's Hi-Tech Military," *Fletcher Security Review*, 26 June 2019.

[102] *TASS*, "Istochnik."

[103] *TASS*, "Noveishii udarnyi bespilotnik 'Okhotnik' sovershil pervyi sovmestnyi polet s Su-57," 27 September 2019.

[104] *Lenta.ru*, "Vedomogo Su-57 svidnuli 'slevo'," 3 August 2020.

Figure 4: S-70 Okhotnik[105]

3.2.2 At sea

The Russian defence industry is trying to develop UUV/USV for the navy. According to official announcements in 2018, 17 designs were under development.[106] Most Western attention has been paid to Poseidon – an autonomous, nuclear-powered intercontinental submarine-based torpedo that could deliver nuclear warheads. It was one of the new super weapons presented by President Putin in his address to the Federal Assembly in March 2018. The Rubin Design Bureau, in St. Petersburg, is the lead developer of the project, with assistance from the Malakhit Design Bureau.[107] The Makeev Missile Centre, in Miass, in the Southern Ural Mountains, is developing the system's launch unit. Knowledge of the project leaked to the public domain in late 2015. Recent evidence, however, suggests that the origins of the project date back to the late Soviet years. In the early 1990s, the new Russian government revived the attempt as the 'Skif' R&D project. Initial details of the project design emerged in 2005. The preliminary design appears to have been completed by 2008, when a first test of a prototype was launched from the Sarov submarine. Several tests have followed since then.[108]

[105] Source: TerHussein, licensed under CC BY-SA 4.0.
[106] Bendett, "The Rise of Russia's Hi-Tech Military."
[107] *Vzglyad*, "V Rossii nachalos razrabotka robotov dlya podlodok pyatogo pokoleniya," 18 March 2016.
[108] *Military Russia,* "Kompleks 2M39 Poseidon/OKR 'Skif' – Kanyon," *blog,* 23 February 2019.

Figure 5: The Posiedon unmanned underwater vehicle[109]

As of 2020, tests of various components were ongoing. A source from the defence industry reported to the *RIA Novosti* news agency that a test of the fully assembled Poseidon was scheduled to take place in the autumn of 2020. It was set to be launched from the nuclear submarine, *Belgorod*.[110] No further information has appeared since then. However, a source in the defence industry indicated to Russian media that the plan is for the Russian navy to procure about 30 Poseidons, to deploy on four submarines. The source did not provide any details on the possible timeline.[111]

3.2.3 On land

Regarding unmanned ground vehicles (UGVs), the Russian defence industry is developing a wide range of systems.[112] Among them are small systems for better intelligence, surveillance and reconnaissance (ISR), as well as large, tank-sized vehicles equipped with long-range, anti-tank and anti-aircraft weapons.[113] The most innovative project is the Marker experimental robotic platform, which is a joint project, initiated in March 2018, between FPI's National Centre for the Development of Technologies and Basic Elements of Robotics and the NPO, 'Android Technology.'[114] The plan is for the Marker to become a fully autonomous UGV.

Another platform that has been developed under a longer period of time is the Uran family of robots. It is being developed by the secretive state-owned company, 766 Office of Production and Technical Completion (766 UPTK), in Nakhabino,

[109] Source: Mil.ru, licensed under CC BY 4.0.
[110] *RIA Novosti*, "Istochnik rasskazal, kogda proidet pervyi pusk 'Poseidona'," 26 May 2020.
[111] *TASS*, "Russian Navy to Put over 30 Poseidon Strategic Underwater Drones on Combat Duty – Source," 12 January 2019.
[112] For a good overview of the many projects, see *RIA Novosti*, "Zheleznaya gvardiya: samye opasnye boevye roboty Rossii," 15 October 2017. The *Kalashnikov* concern is the premier R&D and manufacturing enterprise charged with designing UGVs for various combat needs.
[113] Bendett, "The Rise of Russia's Hi-Tech Military."
[114] FPI, "MARKER," Information Sheet, www.fpi.gov.ru/projects/fiziko-tekhnicheskie-issledovaniya/marker/.

Moscow oblast.[115] There is no information available on exactly when R&D on the Uran robot complex began, but according to the executive director of 766 UPTK, the company has focused its activities on R&D and manufacturing of land-based tactical level robot complexes since 2013.[116] Uran is a whole family of UGVs. Of the several models under development, however, it is the second-generation Uran-9 heavy combat robot that has received the most attention, not least since there is no direct analogue to it elsewhere.[117] It is designed for conducting reconnaissance and fire support for combined arms and reconnaissance units and can be equipped with a wide range of weapons. Uran-9 moves autonomously, but only engages fire after an operator command. It can operate at a distance of three kilometres from its operator.[118]

By 2016, the Uran-9 had passed all state-mandated tests, after which the Russian Armed Forces brought it to Syria for combat testing. Its performance received mixed evaluations. While the MoD described it as excellent, other evaluators claimed that the new system had failed all major criteria.[119] Yet, in January 2019, sources in the defence industry stated that the army had adopted Uran-9 and that production of the first batch of the system was nearing completion. It was also emphasised that Uran-9 provides the scientific and technological basis for future products.[120]

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[115] Since 2019, 766 UPTK belongs to the Kalashnikov Concern, which is the premier R&D and manufacturing group charged with designing UGVs for various combat needs.

[116] *RIA Novosti*, "Dmitrii Ostapchuk: cherez 30 let robot ne ostavit cheloveku mesta na pole boya," 29 November 2017.

[117] Forrest E. Morgan, et al., *Military Applications of Artificial Intelligence: Ethical Concerns in an Uncertain World,* Santa Monica, CA: RAND, 2020, p. 84.

[118] OAO '766 UPTK,' "Boevoi monogofunktsionalnyi robotekhnicheskii kompleks 'Uran-9'," official website.

[119] For a positive assessment, see *TASS*, "Minoborony prodemonstriroval rabotu boevogo robotekhnicheskogo kompleksa 'Uran-9," 7 May 2018. For reporting on a negative assessment, see Dylan Malyasov, "Combat Tests in Syria Brought to Light Deficiencies of Russian Unmanned Mini-Tank," *Defense Blog*, June 18, 2018.

[120] *RIA Novosti*, "Boevoi robot 'Uran-9' prinyali na vooruzhenie rossiiskoi armii," 24 January 2019.

Figure 6: Uran-9 at display in the Army 2016 exhibition[121]

3.3 Horizontal and vertical R&D in AI and autonomy

In comparison with the traditional defence industrial R&D branches, which essentially retain much of the Soviet legacy in terms of divisions, organisations and activities, the new technologies for military applications, such as AI and autonomy, are the subject of several new initiatives. There is a stronger focus in these breakthrough areas on more basic research projects, organised primarily by FPI and RAS. Nonetheless, R&D in AI and military autonomy are horizontal, cross-cutting technology areas, which Russia seeks to integrate into all areas of military R&D. For example, R&D work on developing AI-enabled weapons and unmanned platforms is taking place in aviation, shipbuilding, conventional arms production, and ammunition and special chemicals, as well as in radio electronics and communications systems.

Military autonomy and the development of robotic complexes are clearly a Russian priority, expected to play a predominant role in the future development of Russian military capability. Since 2017, this trend has been and is further fuelled by the government's strong interest in developing AI for military purposes. Indeed, the extensive development work on "combat robots" and "intelligent robot complexes" is expanding to the extent that it might be on its way to establishing

[121] Source: Boevaya mashina, licensed under CC BY-SA 4.0.

itself as a branch of its own within the Russian defence industry, in the same manner as aviation and rocket and space technology were in the previous century.[122]

Weaknesses in the traditional branches of computing and electronics, including the sub-field of semiconductors, however, may present obstacles for Russia's ability to compete successfully in the development of next-generation AI.[123] In this light, the MoD presents the new military technopolis, *Era,* as an integral part of Russia's import substitution policy in the field of software and hardware.

In the field of autonomous and unmanned systems, Russia's military involvement in Syria has had a profound impact on the development, testing, evaluation and use of these systems and platforms. The Syrian experience has also streamlined and centralised efforts related to these technologies. Before Syria, individual R&D initiatives were led by various defence industrial enterprises, rather than being commissioned by the MoD.[124] After Syria, however, the MoD has specified to a higher degree the need for the defence industry to develop unmanned systems that are "able to independently recognise targets, use weapons, and interact in groups and swarms."[125]

In Syria, Russia has made extensive use of UAVs for ISR, providing target destinations, controlling airstrikes and adjusting artillery fire. Syria has also served as a ground for testing and evaluating several new UAVs, UGVs and UUVs.[126] While the results have not always been positive, these combat experiences have nonetheless provided vital information for improving the construction of the weapons as well as valuable insights regarding their tactical use.[127] In sum, the Syrian battlefield has become an integrated part of the R&D process for the robotics complex.

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[122] *RIA Novosti*, "Dmitrii Ostapchuk."
[123] Dear, "Will Russia Rule the World Through AI?" p. 52.
[124] Lavrov, "Russian Military Terrestrial Robots," p. 13.
[125] Samuel Bendett and Martijn Rasser, "Transcript from Russian Advances in Military Automation and AI," Center for a New American Security, 4 June 2020.
[126] Ibid.
[127] Pär Gustafsson, *Metod för framtida motståndarbeskrivning: Tillämpningar på rysk militär förmåga 2045*, Stockholm: Swedish Defence Research Agency – FOI, 2021, p. 47.

4 Conclusions and avenues for future research

Russia retains an extensive military research infrastructure covering all traditional defence industrial branches and providing R&D on armaments for all services of the Armed Forces. The basic military R&D infrastructure consists of three main types of organisations – research institutes, design bureaus and scientific production associations. This vast infrastructure counts approximately 600 organisations that are conducting applied R&D for the defence industry. Territorially, the military R&D organisations are concentrated to major cities, with Moscow and its surrounding areas accounting for almost half of Russia's military R&D entities. Particularly strong areas include aviation research, nuclear technology, information technology and space technology. Meanwhile, the electronics sector remains a problem child, which has become even more troublesome following the sanctions imposed on Russia since 2014. The import substitution policies introduced by the government do not seem to have managed to rectify the problem.

In the era of emerging and disruptive technologies, estimated to reach its maturity within the next decade, the Russian leadership does not appear to deem the defence industry's conventional R&D infrastructure as sufficient for providing the desired breakthrough in critical military technologies. However, with the possibility of declining defence investments in the coming years, the Russian government needs to strike a balance between, on the one hand, costly R&D efforts aimed at modernising existing platforms and, on the other hand, strengthening basic high-risk research aimed at developing new and advanced technologies for military applications.

Given financial constraints, Russia is not spreading its resources across the board. The government has chosen a state-controlled path, where resources and initiatives are pooled into a few selected priority technologies, most notably AI, robotics and autonomous systems. The aim is to catch up with the US and China in these areas and integrate these technologies into innovative weapon systems. While starting from a disadvantageous position, in the past years Russia has made significant advances in developing military robotic systems and introduced AI in its C2 system to shorten decision-making. An advantageous factor for Russia in these technological fields are its strong competence in mathematics and physics as well as its relatively strong pool of computer specialists.

This report has dealt with the institutional and organisational aspects, i.e. the form and function, of Russia's military R&D. The next step would be to examine whether the Russian military research infrastructure is fit for its purposes of achieving breakthroughs in those critical military technologies that are prioritised by the Russian government. In order to assess the qualitative level of Russia's military technological capabilities and the technology maturity levels of certain sectors, more of a technology-driven rather than institutional-driven framework needs to be adopted. Such an approach would be particularly important in a forward-looking perspective of such critical technologies as third-generation AI and advanced autonomy. A concrete step forward could be to identify the prioritised future technologies in Russia and assess their maturity levels. In fields such as AI, potential synergies between civilian and military work is another dimension to take into account.

Another question meriting further study concerns the innovative potential of the Russian defence industry. In this context, the often used dichotomy between modernising older platforms and developing brand new weapons systems is overly simplistic and not always analytically helpful. On the one hand, new generations of defence systems are seldom completely new but originate in older designs. On the other hand, this dichotomy tends to ignore the fact that Russia's present-day modernised T-72 tank, or a Su-27 fighter, represent highly significant improvements compared to previous versions. Overall, it is not so much about building new weapons from scratch as it is a case of cumulative knowledge and development. Large-scale modernisation of older systems is more than gap-filling in anticipation of new revolutionary systems. These modernised platforms, based on continuous R&D, contribute to increasing military capability, even though the systems are based on older designs. Russia has proven quite adapt at developing older ideas and technologies and combining these in innovative ways. In short, Russia's record in this regard deserves to be studied in greater detail.

A final interesting question would be to analyse major advanced Russian weapons systems across all branches of the armed forces, from start to finish, in order to systematically document Russia's record of accomplishments and approximate lead times in the development of weapon systems. Such a study would integrate the R&D phase with the production and deployment phases of initial operational capability and, finally, full operational capability. In this way, more informed assessments of the relationship between military R&D and increased military capability of Russia's Armed Forces will become available.

Appendix

R&D organisations in the shipbuilding industry

Research institutes	**Location**	**Main activity**
Krylovskii Gosudarstvennyi Tsentr	St. Petersburg	Fundamental marine research, shipbuilding
Akusticheskii institut im. N.N. Andreeva	Moscow	Research on acoustics
"Granit-Elektron"	St. Petersburg	Control systems and radar
TsNII "Elektropribor"	St. Petersburg	Navigation equipment, software development
NII "Atoll"	Dubna, Moscow oblast	Geographic surveillance systems
NII "Briz"	St. Petersburg	Technologies for electronic weapons
NII gidrosvyazi "Shtil"	Volgograd	Hydroacoustic communication equipment
NII Morskoi Teplotekhniki	Lomonosov, St. Petersburg	Steam-powered torpedoes
NIPTB "Onera"	Severodvinsk, Archangelsk oblast	Technologies for repair and modernisation of ships
Tsentr tekhnologii sudostroeniya i sudoremonta	St. Petersburg	Fundamental research on technologies for shipbuilding
TsNII "Kurs"	Moscow	Radio electronic equipment for ships
TsNII Sudovogo Mashinostroeniya	St. Petersburg	Marine equipment and devices
Design bureaus		
Zelenodolskoe PKB	Zelenodolsk, Tatarstan	Ship design
KB "Ametist"	Moscow	Radio electronic control system for shipboard artillery
KB Mashinostroeniya	Moscow	Torpedo tubes and missile systems
KB "Vympel"	Nizhny Novgorod	Ship design
Nevskoe PKB	St. Petersburg	Design of aircraft carriers and landing ships
Malakhit	St. Petersburg	Submarine design
Severnoe PKB	St. Petersburg	Design of ships and vessels
SKTB po elektrokhimii s opytnym zavodom	Moscow	Electrochemical systems
SKB Kotlostroeniya	St. Petersburg	Creation of steam boilers for ships and other vessels

TsKB "Aisberg"	St. Petersburg	Designing icebreakers and floating power plants
TsKB "Lazurit"	Nizhny Novgorod	Submarine design and submersible technology
TsKB "Korall"	Sevastopol, Crimea	Designing means for offshore development
TsKB "Monolit"	Gorodets, Nizhny Novgorod oblast	Technology of reinforced concrete floating structures
TsKB morskoi tekhniki "Rubin"	St. Petersburg	Nuclear and non-nuclear submarine design
TsKB po sudam na podvodnykh krylyakh	Nizhny Novgorod	Hydrofoils, air cushion craft and air cavity vessels
TsMKB "Almaz"	St. Petersburg	Design of high-speed combat ships
Scientific production associations		
Dalpribor	Vladivostok	Radio transmitting and receiving, hydroacoustic devices
NPO "Avrora"	St. Petersburg	Automation of nuclear, diesel, and other power plants
NPF "Meridian"	St. Petersburg	Integrated control systems
NPP "Taifun"	Kaluga	Radar stations for ships
NPP "Raduga"	St. Petersburg	Collection and transmission of data
NPP "Salyut"	Moscow	Shipborne radar
NPO "Mars"	Ulyanovsk	Control systems

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