

*Science is essential to people.  
The country that does not advance it will inevitably turn into a colony.  
F. Joliot-Curie.*

## Russian Science and Technology: Rise or Progressive Lag (Part I)

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**Abstract**—The article proposes an approach to a comprehensive assessment of the level of scientific and technological activity in Russia in comparison with leading foreign countries. An analysis has been made of the current imbalances in the development of the scientific and technological sphere in Russia and the reasons for the failure to fulfill many strategic goals. A forecast of scientific and technological development in the context of the existing management system has been made and an assessment has been taken of the potential effect and cost of measures aimed at increasing the technological sovereignty of Russia and the formation of an advanced knowledge economy.

**Keywords:** science, technology, innovation, science financing, technological sovereignty, public administration

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**Introduction.** Almost all countries and experts consider science and technology to be the main driver of modern development. In Russia, science employs almost 0.8% of all those working in the national economy and creates 1.4% of GDP. This is not much, but the overall contribution of science and technology to the development of the Russian economy is many times higher. However, despite certain positive results, in general, the sphere of technological development and especially science is, in our opinion, the Achilles' heel of the modern Russian economy. In fact, the main achievements in this area include the following:

— In the field of innovation, a system of technological and venture development institutions has been created: Rosnano, NTI, Skolkovo, RVC, the Foundation for Assistance to the Development of Small Forms of Enterprises in the Scientific and Technological Sphere (FSI) and a number of other funds.

— Funding for megascience class installations (national project Science and Universities) was increased, a grant system to support scientists and projects was created.

— In 2013–2020, there was an increase in the level of wages in the scientific sector in relation to the corporate sector, an influx of young scientists and researchers increased.

— There are separate breakthrough technological results (nanotubes, vaccines, composites, supercomputers and works on artificial intelligence, nuclear technologies and lasers, hypersound).

— Publication activity of scientists increased.

At the same time, Russia is lagging behind developed countries in terms of R&D funding [1], patent and publication activity, and the number of research personnel is declining. Most target indicators of the Decrees of the President of the Russian Federation of 2012 and 2018<sup>1</sup> for the development of the sphere of science and technology, except for the task of raising wages, have not been fulfilled (Table 1).

In the Concept of Long-Term Socio-Economic Development until 2020 (CLTD)<sup>2</sup> adopted by the Government of the Russian Federation in 2008, the task of Russia's transition to the innovative develop-

<sup>1</sup> Decree of the President of the Russian Federation No. 204 of May 7, 2018, On the National Goals and Strategic Objectives of the Development of the Russian Federation for the Period until 2024; Decree of the President of the Russian Federation No. 474 of July 21, 2020, On the National Development Goals of the Russian Federation for the Period until 2030.

<sup>2</sup> Concept of Long-Term Socio-Economic Development of the Russian Federation for the period until 2020, approved by the Order of the Government of the Russian Federation No. 1662-r of November 17, 2008.

**Table 1.** Results of the implementation of strategic documents for the development of science and technology

Strategic documents	Indicators	Forecast value (estimate)	Year of achievement	Russia 2020 (fact)
Concept of Long-Term Socio-Economic Development of Russia until 2020 and Strategy for Innovative Development of Russia 2020	Research and development expenses, in % of GDP	2.5–3	2020	1.1
	Share of industrial enterprises implementing technological innovations, %	40–50		21.5*
	Share of innovative products, %	25–30		5.7

\* In 2020, the share of organizations implementing technological innovations increased to 23% (up to 21.5% in industry). This growth is associated with a change in international recommendations on the statistical measurement of innovation, implemented by the OECD together with Eurostat (Oslo Manual). The value of the indicator for the Russian Federation for 2017, calculated according to the criteria of the 3rd edition of the Oslo Manual, amounted to 7.5%, when recalculated according to the criteria of the 4th edition of the Oslo Manual, it increased to 20.8%. The difference in the calculation is due to the use of three criteria for classifying an organization as innovative instead of one.

ment of the economy was set. In 2011, the Innovative Development Strategy was adopted, the purpose of which was to increase the innovative activity of business and the efficiency of the transformation of scientific ideas into technologies and market innovations, a state program for the development of science and technology was initiated, as well as a number of other decisions.

However, most of the targets of the CLTD-2020 and the Innovation Development Strategy were not achieved. In particular, domestic expenditures on R&D were planned in 2020 at the level of 3% of GDP, but in fact amounted to only 1.1%. Actually, the indicator of R&D expenses relative to GDP (1%) has been stagnating for almost 13 years. The problems that had accumulated over the years sharply escalated under the conditions of the hybrid war launched by the West against Russia, including actions to isolate the Russian scientific community from world science and a technological blockade.

What resources does Russia have in this war of minds and technologies, and how should the management of the scientific and technological complex be restructured in order to win and lift the country?

**Comparative potential and effectiveness of the scientific and technological complex of Russia and other countries: relative and absolute dimensions.** If in 2008 we were approximately on the same level with China in terms of the relative level of R&D expenses, now China has increased spending to 2.4% of GDP, despite the fact that its GDP is 5.5 times higher than in Russia (Table 2). In the United States, R&D expenses are 3.4% of GDP, in South Korea 4.8% of GDP. Although Russia now ranks 9th in the world in terms of R&D expenses (in terms of purchasing power parity), it is 12.1 times behind China and 15 times behind the United States, and there are all the prerequisites for this gap to widen [2]. In the context of fierce technological rivalry and the hybrid war unleashed against

Russia by the collective West, such an imbalance in power becomes threatening.

If we evaluate R&D expenses taking into account the number of researchers, then the situation in Russia will be even less optimistic: in 2019, 1 researcher (in full-time equivalent) accounted for 3.5 times less research and development expenses than in the United States, and three times less than in Germany. According to this indicator, Russia occupies only 44th place<sup>3</sup> (Table 3).

The national project provided for Russia to maintain the 5th place in terms of the number of researchers in full-time equivalent among the leading countries of the world (according to the OECD) for the period from 2018 to 2021. However, according to the OECD, in 2020 the Republic of Korea overtook Russia in this indicator, shifting it to the 6th position in the rating. Thus, in 2020 Russia is ahead of China (the number of researchers in full-time equivalent is estimated at 2109.5 thousand people), the United States (1554.9 thousand people), Japan (681.8 thousand people), Germany (450.7 thousand people), Republic of Korea (430.7 thousand people). In Russia, this figure in 2020 decreased to 397.2 thousand people versus 400.6 thousand people in 2019. In the leading countries, the number of researchers is growing, while in Russia it has been declining for more than 20 years in a row.

The lag behind developed countries in the field of science and technology is quite large, which creates the preconditions for a “brain drain.” In Germany and the Czech Republic, the salary of scientific workers is 1.9 and 1.3 times higher than the corresponding Russian indicator (the gap for researchers is even higher).<sup>4</sup> However, the issue of brain drain is not so much a

<sup>3</sup> According to the materials of Institute for Statistical Studies and Economics of Knowledge, Higher School of Economics. <https://issek.hse.ru/news/482453668.html>. Cited June 5, 2022.

<sup>4</sup> Source: Federal Office of Statistics of Germany, Bureau of Statistics of the Czech Republic.

**Table 2.** Comparative global dynamics of R&D expenses

Country	R&D expenditures based on PPP, billion dollars		R&D expenses, % of GDP		Including government R&D expenses, % of GDP	
	2008	2020	2008	2020	2008	2020
Israel	8.7	19.8	4.3	5.44	0.5	0.5
Republic of Korea	43.9	112.9	3.0	4.81	0.8	1.1
USA	407.2	720.8	2.8	3.45	0.8	0.7
Japan	148.7	174.1	3.3	3.3	0.5	0.5
Germany	81.2	143.4	2.6	3.14	0.7	0.9
China	145.1	582.8	1.4	2.4	0.3	0.5
France	46.6	74.6	2.1	2.35	0.8	0.7
Great Britain	36.5	56.9	1.6	1.7	0.5	0.5
Czech Republic	3.6	8.9	1.2	1.9	0.6	0.7
Russia	30.1	47.9	0.97	1.1	0.6	0.7

Source: OECD, UK (PPP R&D expenses) 2019, Israel, Germany, France (Public R&D expenses, % of GDP) 2019.

**Table 3.** Place of Russia among the leading countries of the world

	Country	R&D employees by country: 2020 (thousand person-years, full-time equivalent)	Country	Number of researchers by country: 2020* (thousand person-years, full-time equivalent)	Country	Domestic R&D expenses by country: 2020 billion dollars in terms of PPP
1	China	4800.8	China	2109.5	USA	657.5
2	USA	1554.9	USA	1554.9	China	525.7
3	Japan	903.4	Japan	681.8	Japan	173.3
4	Russia	748.7	Germany	450.7	Germany	148.1
5	Germany	735.6	Republic of Korea	430.7	Republic of Korea	102.5
6	India	553.0	Russia	397.2	France	73.3
7	Republic of Korea	525.7	India	341.8	India	58.7
8	Great Britain	486.1	Great Britain	317.5	Great Britain	56.9
9	France	463.7	France	314.1	Russia	45.4
10	Italy	355.9	Brazil	180.0	Taiwan	44.0
11	Brazil	316.5	Canada	167.4	Italy	39.3
12	Taiwan	271.6	Italy	160.8	Brazil	36.3
13	Canada	238.1	Taiwan	159.2	Canada	31.0

\* OECD data. Number of researchers: UK—2007, 2018, China—2012, Germany—2007.

Source: OECD, ANO VEB Institute.

matter of wages, but rather of the opportunity to realize one's potential, the status of a scientist and engineer in society, as well as the access to the global scientific and technological community.

The capital–labor ratio of the scientific sector in Russia today is comparable to that of the scientific sector in the Czech Republic (Table 4).

Naturally, not only the total capital–labor ratio is important, but also the technical equipment of researchers, since the potential capabilities of organi-

zations in obtaining world-class scientific results and their competitive prospects largely depend on the availability of modern scientific equipment. The Decree of the President of the Russian Federation No. 204 of May 7, 2018 set the strategic task of updating at least 50% of the instrumentation base of the leading research and development organizations by 2024. In 2020, less than half (39%) of technical equipment was new equipment under the age of five years. However, most of the research organizations, espe-

**Table 4.** Resources of science: position of the Russian scientific complex

No.	Country	R&D, billion dollars in terms of PPP		Capital-labor ratio, billion dollars		Number of researchers, thousand people		Researcher's salary in 2021 in dollars according to glassdoor.com in terms of PPP *	Patents**, thousand items		Web of science publications, thousand items***	
		2008	2020	2008	2020****	2008	2020*****		2021	2008	2020	2008
1	USA	407.2	720.8	N/A	N/A			10242	429	496	327	606
2	China	145.1	582.8	N/A	N/A		2069.7	4393	204	1441	108	614
3	Japan	148.7	174.1	N/A	N/A	890.7	951.0	6074	510	423	77	117.3
4	Germany	81.2	143.4	N/A	N/A	437.8	667.4	6501	172	168	83	162.5
5	Republic of Korea	43.9	112.9	N/A	N/A	300.1	558.0	4808	173	261	34	86.1
6	France	46.6	74.6	163.0	225.3	289.0	430.0	5436	62	64	62	105.4
7	Great Britain	407.2	56.9	59.6	61.8	377.2	535.5	5780	51	53	86	194.9
8	Russia	30.1	47.9	11.3	18.0	375.8	346.4	3581	31	30	28	84.9
9	Israel	8.7	19.8	N/A	N/A			4845	11	16	12	22.3
10	Czech Republic	3.6	8.9	12.8	12.3	44.2	65.1	4512	2	2	8	22.3

\* Salary is estimated based on machine learning on the basis of millions of salaries from Glassdoor and latest government data sources.

\*\* Patent statistics: <https://www3.wipo.int/ipstats/IpsStatsResultvalue>. Cited June 5, 2022.

\*\*\* Only web of science publications. The dynamics of the number of publications is calculated based on the data of the analytical system InCites (Clarivate Analytics) for Web of Science as of October 31, 2021. A publication means three types of documents indexed in Web of Science: an article, a review and a proceedings paper.

\*\*\*\* France's capital-labor ratio—2019 data.

\*\*\*\*\* Number of researchers in China, Germany, France, UK in 2019.

Source: OECD, Rosstat, National Research University Higher School of Economics, ANO VEB Institute.

**Table 5.** Comparative efficiency of scientific activity

No.	Country	R&D expenses, % of GDP		Capital-labor ratio per researcher, million dollars*		Patents per researcher**		Publications per researcher	
		2008	2020	2008	2020	2008	2020	2008	2020
1	Israel	4.3	5.4	N/A	N/A	N/A	N/A	N/A	N/A
2	Rep. Korea	3.0	4.8	N/A	N/A	0.6	0.5	0.1	0.2
3	Japan	3.3	3.3	N/A	N/A	0.6	0.4	0.1	0.1
4	Germany	2.6	3.14	N/A	N/A	0.4	0.3	0.2	0.2
5	USA	2.8	3.45	N/A	N/A	0.4	0.3	0.3	0.4
6	China	1.4	2.4	N/A	N/A	0.1	0.7	0.1	0.3
7	France	2.1	2.35	0.6	0.5	0.2	0.1	0.2	0.2
8	Great Britain	1.6	1.7	0.2	0.1	0.1	0.1	0.2	0.4
9	Czech Republic	1.2	1.9	0.3	0.2	0.03	0.03	0.1	0.1
10	Russia	0.97	1.1	0.03	0.1	0.08	0.09	0.1	0.2

\* France—capital-labor ratio per researcher, 2018.

\*\* USA (2008, 2020), China (2008)—patents per researcher (thousand person-years, full-time equivalent).

Source: OECD, Rosstat, ANO VEB Institute.

cially those of an applied nature, remained outside the national project and, accordingly, without incentive measures to update the experimental and testing base.

Traditionally, the effectiveness of scientific activity is considered through publication and patent activity. In 2020, Russia ranked 14th in terms of the number of publications in Web of Science and 8th in Scopus; 10th place in terms of the number of applications for a patent for inventions (Table 5). Not the highest result, but its level relative to R&D expenses is very decent. With a significantly lower share of spending on science in GDP, the publication activity of scientists in Russia corresponds to and even exceeds similar values for other developed countries. Accordingly, the relative “cost” of one scientific publication in Russia is lower, which is confirmed by the RSF estimate of the “cost” of publications at the expense of scientific grants allocated by the Foundation, about 2 million rubles for an article in a top-rated journal.

This indirectly testifies to the good performance of the domestic scientific sector, at least in the field of fundamental science, in contrast to the opinion often expressed in the expert community and in government about the inefficiency of Russian science.

The low number of patents (in 2020, Russia was not among the top ten countries), as well as the extremely low share of high-tech exports (the ratio of R&D and high-tech exports) really indicate significant problems with the development of the applied science sector responsible for broadcasting the results of fundamental science in pilot and serial production with the involvement of business funds represented by public and private companies and corporations (Fig. 1). It should be taken into account that such exported high-tech products as nuclear fuel and reactors, according to the international classification, do not belong to high-tech exports. Nevertheless, this does not change the overall low rating of Russian high-tech exports.

For all the importance of the science-intensive export factor, it is necessary to take into account the significant structural difference between the Russian scientific and technological complex and other developed countries. Historically, it was focused not on exports, which were mainly raw materials, but on solving the internal problems of the state, including those related to defense capability. The structure of scientific publications, as well as patent activity in Russia, is largely concentrated in the fields of mathematics, physics and engineering, in contrast to medicine and information technology, which are a priority in the West.

We have yet to create a truly realistic comprehensive system for assessing the achieved scientific and technological potential instead of fragmentary indicators borrowed from Western experience. We need new criteria (except for publications and patents) and a new science assessment system based on a qualified expert assessment, indicators of work with the industry, pro-

motion of R&D results by levels of technological readiness. According to the President of the Russian Academy of Sciences A. M. Sergeev, “the main result will not be an article, but an expert assessment of specialists and the final product”.<sup>5</sup>

In various coordinate systems of scientific and technological activity, Russia occupies from 6th to 12th place (Table 6). According to a comprehensive assessment of ANO VEB Institute,<sup>6</sup> in 2019 we have an honorable 7th place in the world table of scientific ranks.

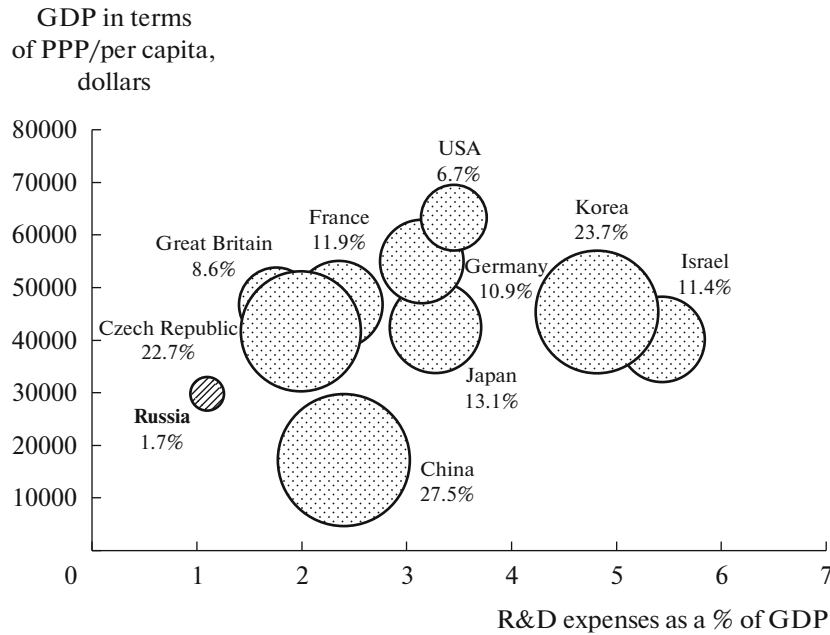
In general, in terms of the level of scientific and technological activity, Russia is approximately in the same place as in terms of GDP in terms of purchasing power parity. Such positioning is more characteristic of an economy that is trying to gain a foothold on what has been achieved, with the risk of losing its occupied place, than for an economy that is breaking through upwards.

***Science and technology policy priorities in Russia: controversial searches.*** What are the reasons for this huge discrepancy between ambitious goals and modest results? The year of science has ended, but there has been no visible scientific and technological upsurge.

The first reason is chronic underfunding, usually explained by insufficient efficiency, and by reference to the high share of public funding compared to Western countries. True, in terms of absolute volumes, both state and, even more so, private funding per employee or per key area of research and development is extremely small. At the same time, Russian private business with large incomes, unlike Western countries, is concentrated mainly in the fuel and energy and raw materials sectors, where the relative level of R&D expenses in the West is also low. On the whole, in terms of the relative (to revenue) level of R&D

<sup>5</sup> A. M. Sergeev, How can we do science under sanctions? <https://rg.ru/2022/05/31/1-iunia-sostoiatsia-vybory-novyh-chlenov-rossijskoj-akademii-nauk.html>. Cited June 5, 2022.

<sup>6</sup> The assessment is based on a modified methodology of the Russian Ministry of Education and Science for calculating the indicator “Place of the Russian Federation in terms of research and development, including through the creation of an effective system of higher education.”  $PRF = (PRFOESD \text{ in terms of the number of researchers in full-time equivalent among the world's leading countries} \times 0.3) + (PRFDRDE \text{ in terms of research and development expenses} \times 0.3) + (PRF A \text{ in terms of share in the total number of articles indexed in international databases data} \times 0.15) + (PRF P \text{ in terms of share in the total number of patent applications} \times 0.2) + PRF TOP500 \text{ in terms of the presence of top 500 universities in the QS ranking} \times 0.05)$ . The indicator is expressed in whole units, and the weight coefficients are based on an assessment of the impact of the components of the statistical indicator on the development of the scientific and technological complex of the Russian Federation. The data are divided into main areas: resource potential (based on the indicators of staffing and the state's financial expenses on research and development), the effectiveness of scientific activity (based on indicators of publication and patent activity), as well as the effectiveness of the higher education system based on the position of Russian universities in the international QS ranking.



**Fig. 1.** Comparison of the level of development of the country, R&D expenses and technological exports, 2020 (the size of the “bubble” is the share of high-tech exports in exports).

expenses, but not in absolute terms, our leading industrial companies are not inferior to Western ones.

Despite the implementation of the Presidential Decree to increase the salaries of scientists included in the target categories, the prestige of scientific activity is not increasing, while the inflationary surge in the scientific and educational sphere in 2022 has so far remained without adequate compensation. All this contributes to the continuation of the trend towards a reduction in the number of scientists and researchers. There is still a shortage of modern scientific equipment, especially of domestic design, with a limited scale of implementation of megascience projects in Russia, despite the PIK and SKIF projects.

The second reason, perhaps more important, is the lack of a systematic, consistent policy for the development of science and technology and a “lost aim of priorities and principles.” We are persistently trying to develop the scientific and educational sphere along the American path, relying on the leading role of universities in the development of science and the formation of a venture capital market as the basis for innovative technologies and projects. However, the Russian tradition is closer to the German model and its advantage, rather than disadvantage, is the presence of powerful academic institutions and industry science, including in the form of state research centers (SRCs) [3].

Despite repeated attempts to reform the field of science and create a modern innovation system, one can speak of a crisis in the management system of the country’s scientific and technological complex.

The list of priority areas and critical technologies has been updated long time ago, in 2002, 2006, 2011 and 2015.<sup>7</sup> Despite the fact that the number of positions in the list of critical technologies has consistently decreased, none of the lists was accompanied by an indication of additional funding for the priorities included in the list, as a result of which it did not become a real tool for highlighting the most important areas, and is mainly used for ritual references in the preparation of various scientific programs and funding applications. In the Strategy for Scientific and Technological Development of the Russian Federation (SNTD), a list of seven areas appeared, which actually began to be used as a priority. They were based on an analysis of the “big challenges” facing the country, and they were supposed to be specified at the next stage, which was never implemented.

In the new version of the state program “Scientific and technological development of the Russian Federation” (SP STD),<sup>8</sup> an attempt was made to formally align projects and financing instruments under the logic of priorities set in the STD Strategy. To do this, the research work that was previously carried out by line ministries is rather schematically combined into

<sup>7</sup> Program of fundamental scientific research in the Russian Federation for the long term (2021–2030), approved by the Order of the Government of the Russian Federation No. 3684-r of December 31, 2020.

<sup>8</sup> State Program “Scientific and technological development of the Russian Federation,” approved by the Decree of the Government of the Russian Federation of March 29, 2019 No. 377 (as amended by the Decree of the Government of the Russian Federation No. 1814of October 22, 2021).

**Table 6.** Comprehensive assessment of the place of the Russian scientific complex in the world

Country	Resources		Results		Top 500 universities	Final place
	DRDE	Researchers	Publications	Patents		
USA	1	2	1	2	1	1
China	2	1	2	1	5	2
Japan	3	3	6	3	6	3
Germany	4	4	4	5	3	4
South Korea	5	5	13	4	8	6
France	6	8	7	26	7	10
Great Britain	7	7	3	6	2	5
Russia	8	6	12	11	7	7
Italy	9	9	8	10	10	8
Canada	10	10	9	13	6	9
Spain	11	11	11	22	10	12
Netherlands	12	13	15	8	9	11
Switzerland	13	18	19	7	13	13
Sweden	14	14	20	12	13	14
Belgium	15	15	22	16	14	15
Poland	16	12	17	29	19	17
Austria	17	16	26	15	16	16
Singapore	18	23	33	25	18	20
Denmark	19	20	24	17	16	18
Czech Republic	20	19	27	34	18	21
Finland	21	21	36	20	13	19
Norway	22	24	32	28	17	22
Ireland	23	25	44	27	16	23
Portugal	24	17	25	74	17	25
Hungary	25	22	48	39	20	24
Slovenia	26	27	56	56	20	28
Slovakia	27	26	49	54	20	26
Luxembourg	28	28	76	31	20	27

Source: OECD, ANO VEB Institute.

large blocks to correspond to the various priority areas of the Strategy, which in essence is a matter of classification, but not the allocation of real priorities for the purpose of their priority funding. The old system of determining the priorities of technological development by the Presidential Decree does not work, and a new integral system has not been formed. Under these conditions, the plans for scientific research (government order) do not meet the breakthrough tasks and global challenges facing the country, and are largely guided by the principle “by what has been achieved.”

A partial selection of priorities based on forecasting new markets was also carried out during the formation of the National Technology Initiative (NTI) [4]. The Presidium of the Council under the President of the Russian Federation for the Modernization of the

Economy and Innovative Development of Russia approved seven roadmaps: Autonet, Aeronet, Marinnet, Neuronet, Technet, Healthnet, Energynet. To date, the number of NTI directions has increased to 13, Foodnet, Safenet, Edunet, Sportnet, Homenet, Wearnnet have been added. However, the fashion and e-sports markets can hardly claim the role of a priority area for research and development.

In 2022, at a meeting of the Council for Science and Education under the President of the Russian Federation, three new most important innovative projects of national importance were announced, which can also be considered as a choice of priorities:

— Russian scientific and technological platform for rapid response to infectious diseases.

**Table 7.** State program for the development of science and technology (old and new), billion rubles

Indicator	2022		2023		2024	
	old	new	old	new	old	new
SP STD	838.5	1075.5	881.8	1138.9	957.2	1173.5
FP	119.1	251.2	140.7	282.3	N/A	262.4
Departmental project	0.02	75.9	0.02	64.4	N/A	61.3
OM	719.4		741.0		N/A	
FTP		0.6		0.6	N/A	0.6
Complex of process measures		744.8		788.6	N/A	846.2

Source: ANO VEB Institute.

— Creation of the Unified National Monitoring System for Climatically Active Substances.

— Low-carbon closed-loop energy.

Despite the relevance of these topics, taking into account the challenges of the COVID-19 epidemic [5] and the tasks of adaptation to climate change, in the context of a hybrid war, their priority is relatively reduced.

The now adopted new SP STD (funding is approved only until 2024) for 2022 provides for funding in the amount of more than a trillion rubles, but this is ensured mainly by including in the SP STD the amount of funding for research and development previously ordered by line ministries—the Ministry of Industry and Trade of Russia, the Ministry of Health of Russia and other departments. In other words, the apparent increase in funding for the new state program is associated with the merging into one program of all projects and major events, in the name of which there was the word “scientific ...” from the rest of the state programs, while the coordination of all the former industry R&D of the Ministry of Education and Science has not been worked out yet. Such an association does not imply real coordination of projects. In nominal terms, until 2024, an average annual growth of funding by 0.9% per year is planned, which means a decrease in funding in real terms (in the old program for 2020, an increase of 2.7% per year was planned) (Table 7).

In our opinion, in the new SP STD, taking into account the experience of NTI and road maps, it is necessary to single out specific scientific and technological areas, ensuring their priority funding [6]. A significant part of the scientific community agrees that these are artificial intelligence, microelectronic, photonic and quantum technologies, new materials and additive manufacturing, the Internet of things and

5/6G communications, medical technology and pharmacology, genetic and biotechnologies.<sup>9</sup>

**Management dramas or barriers in the circulation of ideas and innovations.** The development of science is the responsibility of the Ministry of Science and Education, while technological areas are the responsibility of line ministries, from the Ministry of Industry and Trade to the Ministry of Defense. The Academy of Sciences, although it did not turn into a club of scientists, lost the status of a scientific organization after the reform of 2013 and has rather an informal influence on the management of the scientific and technological process.

By Decree of the President of the Russian Federation No. 143 of March 15, 2021, On Measures to Improve the Efficiency of the State Science and Technology Policy, the functions of determining the strategic goals, objectives and priorities of the scientific and technological development of the Russian Federation are assigned to the Council under the President of the Russian Federation for Science and the permanent Commission on Scientific and Technological Development of the Russian Federation under the Government of the Russian Federation. However, the new functions and the creation of the commission did not change the nature of the management of the scientific and technological complex. The plurality and diversity of priorities at various levels indicate the absence of a coordinated system for determining the scientific and technological goals of these priorities, which then inevitably manifests itself both in their resource provi-

<sup>9</sup> A. M. Sergeev, How can we do science under sanctions? <https://rg.ru/2022/05/31/1-iiunia-sostoiatsia-vybory-novyh-chlenov-rossijskoj-akademii-nauk.html>. Cited June 5, 2022; A. N. Klepach, Socio-technological challenges of the Russian economy, Moscow Economic Forum MAEF. <https://cyberleninka.ru/article/n/sotsialnyei-tehnologicheskie-vyzovy-rossiyskoy-ekonomiki/viewer>. Cited June 5, 2022.



sion and in the concentration of managerial efforts in accordance with the designated goals. The expert potential of the Academy of Sciences is used to a small extent when considering key strategic decisions and large-scale scientific, technological and spatial projects in managing the development of science and technology.

The Ministry of Education and Science, currently mainly focused on higher education issues and the scientific agenda, especially applied science, is on the sidelines, while the importance of developing scientific and technological groundwork in the activities of sectoral departments is declining under the influence of a wave of current sectoral problems. In contrast to Soviet times, the coordination of scientific and technological developments in the civil and military spheres is also at a low level. For all the relativity of international university rankings, despite additional funding in the amount of 80 billion rubles, none of the universities participating in the 5/100 project has made it into the top 100 world rankings.

An analysis of the volume and structure of financing of the state program “Scientific and technological development of the Russian Federation” until 2024 also indicates that its main expenses go to the implementation of the subprogram “Ensuring the global competitiveness of Russian higher education”—ensuring current expenses for the implementation of educational programs and activities of higher education organizations within the framework of the Priority 2030 program and SECs. The share of the educational block in 2021–2023 accounts for 66.5% of the state program. Financing of directly scientific and scientific and technological activities is carried out according to the residual principle [7].

The process of creating scientific and educational centers (SECs) has not yet led to the formation of new scientific and educational consortiums capable of solving large-scale scientific problems. The educational agenda in them dominates over the scientific one. SECs do contribute to the involvement of scientists in the development of universities, but do not create conditions for the joint work of educational institutions with academic institutions as integral entities.

Prospects for the development of fundamental science until 2024 are largely determined by the implementation of the program of fundamental research and the participation of RAS institutes in the activities of the national project “Science and universities” through the activities of world-class scientific centers, centers for genomic and mathematical research, centers of the NTI competencies, programs for the creation of research facilities of the megascience class. The development of the system of grants from science foundations has given the support of basic science an important flexibility and individuality. At the same time, the loss of scientific status by the Academy of Sciences and the lack of coordination of its actions

with the Russian Science Foundation, after its actual merger with the Russian Foundation for Basic Research, further increases disunity in the scientific community and its management system [8].

The attempts made to build an integral system from fundamental research through exploratory scientific and technological work to applied innovative developments, or an innovative lift, have not yet been successful. An example is the initiative of development, which is almost four years old, of complex scientific and technological programs of the full innovation cycle (CSTP), which provided for large-scale world-class scientific and technological projects, including in such important areas as new substances and materials, specialized robotics, baby food. For four years there has been discussion and adjustment, but not a single program has been launched. According to the idea, the state planned to provide support for exploratory R&D, and business was supposed to finance applied research and bring innovative products to the market, which ensured the unity of fundamental and applied science. So far, there is progress only in terms of business financing, in particular through Rosatom, but without state support. After the reformatting of the national project “Science” into “Science and Universities” in 2020, the development of CSTP actually became a nonpriority. In the approved SP STD, the planned financing of CSTP was reduced to two billion rubles per year (10 times less than the original passport of the national project “Science”), which does not allow us to consider even the already approved CSTP as powerful driver programs for the full scientific and technological cycle.

Currently, along with projects in industry state programs, a really significant state tool for the development of new scientific and technological areas in terms of applied and corporate science are the roadmaps of state companies launched in 2019 for the development of a number of high-tech areas, as well as “beacon projects” approved by the Government as part of strategic initiatives in 2021 as a continuation of the National Technology Initiative (NTI). It is assumed that the “beacon projects” of technology development should have a high multiplier effect for the development of the economy. In our opinion, beacon projects are more likely to be targeted innovative projects and do not have a large macroeconomic effect in the medium term, with the exception of the electric propulsion project. Moreover, they do not create a need for in-depth fundamental and exploratory research, nor do they entail any significant increase in country R&D expenses. These projects are, in essence, a continuation of the priorities adopted at the launch of the National Technology Initiative, a kind of NTI 2.0 [9].

To a large extent, there is no synergy of beacon projects with research and projects carried out within the framework of the roadmaps of state-owned com-

**Table 8.** Structure of internal current research and development expenses by type of work in 2020, %

Country	Fundamental research	Applied research	Development
USA	16.4	19.0	64.5
China	6.0	11.3	82.7
Japan	13.0	19.4	67.6
Republic of Korea	14.7	22.5	62.8
France	22.7	41.4	36.0
Great Britain	18.3	42.1	39.7
Russia	18.8	20.0	61.2
Israel	10.0	10.1	79.9
Czech Republic	26.2	41.1	32.3

Source: OECD, Rosstat.

panies and the activities of the SP STD, except for the areas of ICT and artificial intelligence technologies.

In the world practice of managing and supporting new areas of scientific and technological development by the state, the emphasis is on numerous research programs and partnerships created specifically to organize and support research in the field of new technologies, targeted funding is also provided through grant funds.

For example, in the field of quantum technologies at the EU level, the Quantum Flagship program (2018–2027) [10] is operating, and Germany is implementing the National Quantum Program (2021–2028). In the United States, in the field of new technologies in the electric power industry, there is the DOE Grid Modernization Initiative, a large program for the modernization of the US electric networks, which involves 17 national Laboratories operating under the auspices of the US Department of Energy [11].

These are quite long-term programs, while in Russia budget financing of roadmaps and programs is provided only until 2024. In particular, in the program “Digital economy of the Russian Federation”: for the development of quantum computing (13.3 billion rubles), artificial intelligence (24.6 billion rubles), 5G mobile communication networks (21.463 billion rubles), quantum communications (10.2 billion rubles). All together, these roadmaps cost about 1 billion dollars. State support abroad for similar areas is much larger: in the direction of quantum computing, in the United States—1.2 billion dollars, programs of the EU and individual European countries—a total of more than 5 billion euros, India—1.12 billion dollars; in the direction of artificial intelligence, China—8 billion dollars, the United States — 6 billion dollars, programs of the EU and individual European countries—a total of more than 7 billion euros; in the direction of quantum communications, China—more than 15 billion dollars, Germany—more than 2 billion euros. At present, monitoring of the implementation

of roadmaps by the state is entrusted to the Ministry of Economic Development of Russia.

The overall structure of science expenses in Russia is close to the similar structure in foreign countries. However, as is known, it is the sphere of applied research and development that is the most financially and capital intensive, while in Russian conditions it is here that the main deficit of investments and equipment is concentrated (Table 8) [12].

At present, the weakest link in the structure of the Russian scientific and technological complex is the link that ensures the transition from the stage of research and laboratory samples to pilot plants and small-scale production (TRL 4–7),<sup>10</sup> refining and scaling new technologies.

The main potential of applied and engineering research in Russia is concentrated in the system of state research centers of the Russian Federation and in the field of corporate science, concentrated mainly in the largest state corporations and companies with state participation.

The system of the public sector of applied science is the most important component of the national innovation system and unites 44 scientific organizations with the status of state scientific centers, the activities of which are aimed at creating and developing tech-

<sup>10</sup>TRL. There are nine levels of technology readiness. From the first to the sixth levels, this is the development of technologies, which is carried out within the framework of research and development. From the seventh level and above, development engineering begins, or a demonstration of the operability of technologies on real devices under development. TRL 1—approval and publication of the basic principles of technology, TRL 2—formulation of the concept of technology and evaluation of the scope, TRL 3—beginning of research and development. Validation of characteristics, TRL 4—verification of the main technological components in the laboratory, TRL 5—verification of the main technological components in real conditions, TRL 6—testing a model or prototype in real conditions, TRL 7—demonstration of a prototype (trial model) in operation, TRL 8—completion of development and testing of the system in operation, TRL 9—demonstration of the technology in its final form during flight tests of the sample

nologies, promoting the results of search, applied research and experimental development, including their own production of high-tech goods.

Today, the system of state research centers of the Russian Federation in terms of its functionality and variety of work performed is comparable to the world's largest associations that carry out applied problem-oriented research and development, such as the Fraunhofer Society (Germany) and the network of Carnot Institutes (France).

The fundamental difference between the state research centers of the Russian Federation and academic and university science is the predominance of expenses on applied research and experimental development. Despite the fact that all state research centers of the Russian Federation are only 1% of the country's organizations performing research and development, they account for 20% of the country's expenses for applied research as part of DRDE. At the same time, the share of state research centers of the Russian Federation in DRDE across the country in 2020 reached 7.7% (91.1 billion rubles). At the same time, the share of R&D expenses in the DRDE structure at the expense of nonbudgetary sources in the system of state research centers of the Russian Federation exceeds 50%.

At the present stage, the problem of further development of the system of state research centers of the Russian Federation, as well as of all applied science in the Russian Federation, is, among other things, insufficient legal support for such activities. It is advisable to update the normative and managerial categories "applied scientific research," "exploratory scientific research," "experimental developments," "scientific

and technological groundwork," to consolidate the concept "innovative projects of a full life cycle." Groundbreaking work does not fit into the procurement system according to Federal Law No. 44-FZ of April 5, 2013, On the Contract System in the Field of Procurement of Goods, Works, Services to Meet State and Municipal Needs, and Federal Law No. 223 of July 18, 2011-FZ, On the Procurement of Goods, Works, Services by Certain Types of Legal Entities, and they need a special management system and their own special regulatory framework [13].

Despite the significant potential, the state's attention to the development of the system of state research centers of the Russian Federation is almost absent. It should also be noted that the functions of managing applied research are not provided for in the regulations of any federal executive body. As a result, today hardly anyone is directly responsible for supporting applied science in the country.

It is advisable to create a special section (target item of expenses): "Research and development carried out by state research centers of the Russian Federation," which implies targeted budgetary financing of research and development carried out by the state research centers of the Russian Federation according to agreed development programs, including for organizations that have an organizational and legal form of commercial organization.

The status of state research centers should be clarified, both taking into account the American experience of "national laboratories" and the experience of the Kurchatov Institute and the Zhukovsky Center for Scientific Research, for which special legal acts were adopted.

**Table 9.** R&D expenses of the largest state-owned companies by industry

Sectors of the economy	R&D spending	2017	2018	2019	2020
Space sector	pace		104.2	92.8	235.5
	% of revenue	54.3	61.9	57.6	51.5
Aircraft industry	pace		92.0	146.7	67.0
	% of revenue	10.0	10.2	18.6	10.2
Shipbuilding, automated control systems and marine engineering	pace		78.9	86.7	94.9
	% of revenue	13.4	10.4	8.2	7.3
Chemistry and pharmaceuticals	pace		86.5	67.0	94.9
	% of revenue	22.7	18.3	28.8	23.2
Extraction and processing of raw materials	pace		109.5	106.5	91.7
	% of revenue	0.2	0.2	0.3	0.3
Energy	pace		108.1	124.7	167.5
	% of revenue	0.5	0.6	0.6	1.1
Transport and infrastructure	pace		199.3	109.7	95.7
	% of revenue	0.3	0.7	0.7	0.7
Communications and telecommunications	pace		150.4	143.4	102.8
	% of revenue	1.2	1.1	1.5	1.4

Source: Ministry of Economic Development of Russia, ANO VEB Institute.

It should be noted that more than 40% of the total national funding for the physical and technological sciences is concentrated in the system of US national laboratories, while federal funding accounts for up to 70% of all R&D expenditures, primarily for the operation of unique scientific facilities used by universities and industry. Many national laboratories operate in a government-owned, contractor-operated format, a model that enables breakthrough research in promising areas based on the use of large state-funded scientific facilities and equipment and the private initiative of the contractor. At the same time, network interactions formed for specific tasks allow national laboratories to solve interdisciplinary problems in a wide range of areas [14].

In general, the formation of intersectoral, interdisciplinary national research centers of applied science on the basis of the leading state research centers of the Russian Federation and the scientific research centers, following the example of the Kurchatov Institute and the Zhukovsky Center for Scientific Research, will allow planning and implementing complex scientific and technological projects and full-cycle programs that meet the challenges and priorities of the Strategy for Scientific and Technological Development of the Russian Federation.

The system of innovation development institutions that has developed in Russia is mainly focused on a variety of startup support mechanisms: the Innovation Promotion Fund, the Skolkovo Foundation, Rosnano, NTI, RVC, etc. The activities of development institutions, for all their importance for the development of innovations, are characterized by limited scientific, especially the fundamental, component. Domestic startups in the overwhelming majority do not develop, but use technologies of varying degrees of readiness for the commercialization of products based on them. The few exceptions are the most successful projects of Rosnano (for example, the company Oscial in the field of nanotubes). The bottleneck in the scientific and innovation cycle is the stage of pilot development and scaling, which in the current system of development institutions can be mainly handled by Rosnano only (to a lesser extent, by FRP and FPI). Currently, VEB.RF is in charge of coordinating development institutions, and a new model of interaction (“seamless integration”) and the so-called “innovation lift” still needs to be developed.

Applied science in Russia is concentrated mainly both in state research centers and in the largest state corporations and companies with state participation, which are obliged to implement innovative development programs (IDP) since 2011 [15] (Table 9). At present, the list of state-owned companies implementing IDP includes 57 state corporations, joint-stock companies and federal state unitary enterprises. In 2020, the total expenses of state-owned companies for the implementation of IDP amounted to about

1.4 trillion rubles, total R&D expenses 552 billion rubles. At the same time, state-owned companies’ R&D expenses reached 232 billion rubles, which is more than 60% of applied science expenses for the Russian Federation as a whole.

The range of technologies developed by state-owned companies is very wide, and, as can be seen from Fig. 2, in a number of traditional areas in general, according to the companies themselves, it is not inferior to the level of development in the leading foreign peer companies. However, in terms of microelectronics technologies, space and energy technologies, there is a significant lag behind the world level.

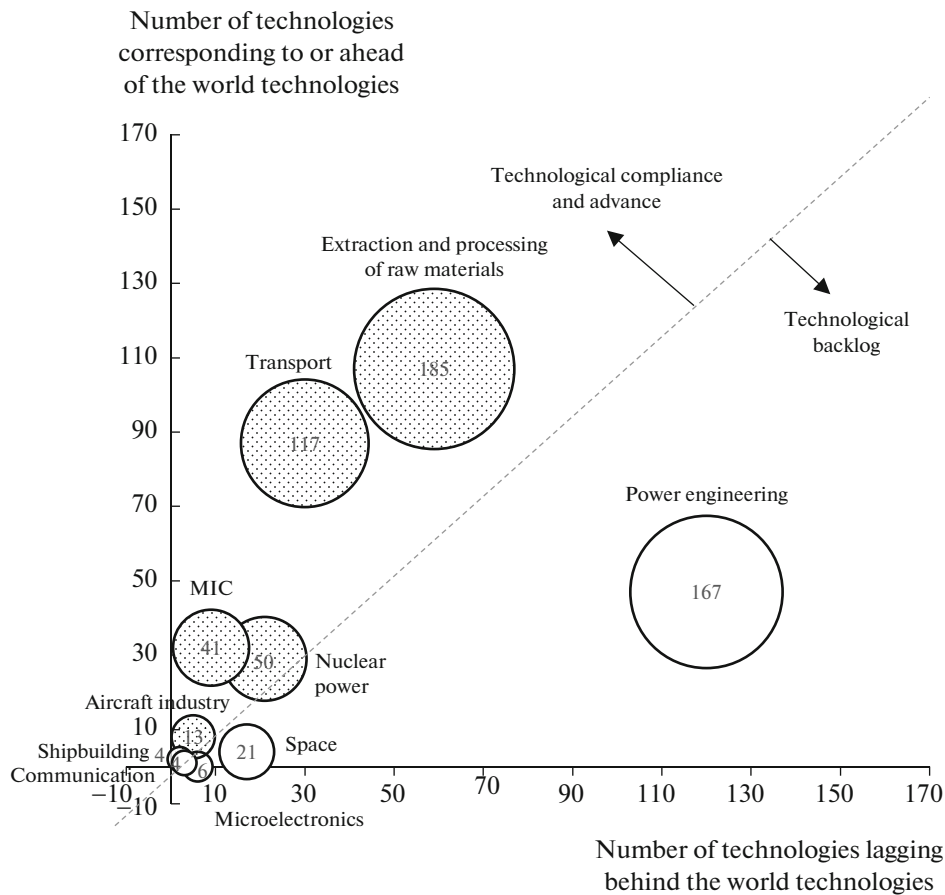
At the same time, state-owned companies note that there is a shortage of breakthrough promising research that cannot be overcome by corporate research centers and state research centers, and therefore special approaches and mechanisms are needed to support the formation of scientific and technological groundwork and breakthrough risky developments. At present, business mainly plans its activities in the short and medium term and is not ready to set fundamental tasks for scientists that require serious exploratory research.

Despite calls for an outpacing increase in private R&D funding, state-owned companies have not increased R&D expenses in recent years, and somewhere have lowered its relative (to revenue) level.<sup>11</sup> The state, through its representatives on the boards of directors, does not set them the task of increasing these expenses. In many ways, this is not just the result of inconsistency with the budget plans of corporations, but the lack of long-term sustainable priorities for technological and innovative development on the part of the state and companies.

At present, all FEED projects are financed in a general manner within the framework of investment programs of state-owned companies, and priority is usually given to low-risk projects with a high share of mastered imported technologies. In the new times that have come, the requirement to ensure technological sovereignty forces the creation of high-risk projects with a significant innovative and breakthrough component.

Attention to FEED in recent years has been pushed aside by the demand for the implementation of specific KPIs, mainly of a volumetric financial focus. It is advisable not to abolish, but to reformat the innovative development programs of state-owned companies

<sup>11</sup>FEED is a comprehensive tool for the development of innovations in companies, their structure includes activities in the following areas: development and implementation of innovative projects, improvement of innovation management mechanisms in companies, including in the field of intellectual property, development of an ecosystem of “open innovations” through interaction with small and medium-sized companies, organizations of science, higher education and objects of innovation infrastructure (innovation clusters and technology platforms), development of mechanisms for financing and investment in the innovation sector (including venture funds).



**Fig. 2.** Comparative level of technological development of state-owned companies. The size of the “bubble” corresponds to the number of technologies analyzed.

(FEED 2.0) and their financing mechanisms, not excluding their transformation into subprograms of long-term programs for the development of state corporations. The need for stimulation, and for “forcing innovation” has not yet disappeared. The following necessary institutional innovations can be identified:

- Highlighting, as part of innovative development programs (DPR subprograms), of activities that are part of the roadmaps for the implementation of agreements between companies and the state on the development of advanced technologies; combining innovative programs with corporate digitalization programs and programs to reduce greenhouse gas emissions in order to avoid the multiplication of organizational structures within companies and the dispersion of efforts following every trendy agenda.

- Providing public-corporate innovators with the right to take risks when conducting research in the early stages and transition to managing a portfolio of innovative projects instead of waiting for the economic efficiency of each project.

- Initiating the creation of new ways for financing innovative projects at the stages of R&D and development through specialized corporate innovation sup-

port programs and corporate venture funds, or industry-specific R&D funds with a deduction of 1.5% of profits under the current legislation.

- Encouraging corporate science to start research in breakthrough technological areas (for a 10–15 year perspective), which require fundamental/exploratory work to be carried out jointly with external partners.

Thus, based on the results of the comparison of the level and trends in the development of the scientific and technological sphere in Russia with the leading foreign countries, carried out in this article, we can conclude that there is a potential in the field of fundamental science and high-tech big business that is sufficient to maintain technological parity. At the same time, for a technological breakthrough with the aim of Russia’s entry into the top five countries—world technological leaders—it is necessary to solve a set of problems related to the multiplicity of scientific and technological priorities, restrictions on the financing of science and the inconsistency of policy in relation to state programs of scientific and technological development, as well as insufficient support for the applied and corporate science sector.

In this regard, in the second part of the article, a set of measures will be proposed to accelerate scientific and technological development, including taking into account the need to level significant restrictions in which the domestic science sector found itself in conditions of technological blockade.

#### CONFLICT OF INTERESTS

The authors declare that they have no conflicts of interest.

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