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CRITICAL TECHNOLOGIES IN RUSSIA: IDENTIFICATION AND IMPLEMENTATION

Key words

Long-term forecasting, foresight, critical technologies, S&T priorities, monitoring.

Abstract

Lists of S&T priorities and critical technologies have been compiled in Russia since 1996 as a management tool for innovation development process. They are regularly updated, and in 2011, a new list consisting of 6 priorities and 27 critical technologies was approved. The article analyses the approaches to setting up and adjustment of critical technologies lists, including a detailed description of applied methodology and expert procedures. Special attention is paid to consistency between this research and other long-term S&T foresight activities. Also highlighted are such issues as practical application of high-priority and critical technologies and the prospects for the establishment of a system for monitoring this process. The article was written in the framework of The Basic Research Program of the Higher School of Economics in 2012.

Introduction

Setting priorities in the S&T area has recently became one of the most important instruments for S&T and innovation policy. One of the key studies, which largely determined the subsequent approaches to the selection of priorities, was the work [1] that proposed their widespread use in various

industrial sectors as one of the criteria for classification technology as a critical. The instrument now is widely used in developed countries [2, 3]

Presently, a significant experience of developing a national system for identification of priority S&T development areas has been accumulated in Russia. Priority areas for science and technology development and a list of critical technologies[1] had been officially approved in Russia for the first time in 1996 and have been repeatedly updated. While the original list consisted of a substantial number of critical technologies, a trend has emerged towards reducing its number (Table 1).

Table 1. Retrospective of Russian priority lists

Year	1996	2002	2006	2011
Number of PA	7	8	8	8
Number of CT	70	52	34	27

This trend can be explained by the need to concentrate resources on a limited number of the most important key S&T areas with a potential to assist in achieving national competitive advantages in the medium and long term, and meet the global and national challenges.

The most recent projects (implemented in 2006 and 2011) were based on the standardised foresight methodology [4, 5], which implies the application of various expert evaluation techniques, including recommendations and proposals developed by federal executive agencies, leading Russian scientists and practitioners, and managers of large companies, covering the whole range of priority development areas, as well as expert polling and expert discussions [6, 7].

The key feature of the approach used to select S&T priorities was an orientation towards the implementation of the innovation potential of Russian technologies in the form of particularly important products and services. Priorities identified in the course of the previous project served as the basis for developing the structure for the federal targeted programme "Research and development in priority areas of developing Russia's S&T complex in 2007––2012." They were also used to develop the structure for Russian S&T

[1] Priority science and technology area is a subject area in the science and technology field of an inter-industry (inter-disciplinary) significance, which can make a biggest contribution to ensuring national security, accelerating economic growth, increasing the country's competitiveness by advancing the economy's technological basis and promoting research-intensive production.
Critical technology is a set of inter-industry (inter-disciplinary) technological solutions which create conditions for further development in various technological subject areas; have a wide range of competitive technological applications in various industries; and taken together, make a biggest contribution to achieving progress in priority S&T development areas.

development forecast up through 2025 and to compile the current lists of S&T priority areas and CTs[2] described in more detail below [8].

In the first part of this article, the procedure for selecting S&T priorities and used methodology are represented. Then the achieved results are described. After that, ways for their realisation of identified CT are outlined and the results of monitoring are presented.

1. Procedure for selecting S&T priorities

The last round of selection of S&T priorities (2011) was different from all the previous ones, due to its pronounced orientation towards practical application according to the new methodology [9]. It was focused mainly on the R&D areas with a potential for quick commercialisation, and capable of generating a significant socio-economic impact. The experts concentrated efforts on evaluating the potential demand for innovative products/services and identifying relevant key technologies for their production, and on R&D and production potential of Russian organisations.

The selection of S&T priorities was based on the following criteria:

- Improving the quality of life;
- Ensuring a high rate of sustainable economic growth (contribution to accelerated GDP growth, improvement of its structure, increased competitiveness of the Russian economy, including the production of competitive products for domestic and international markets);
- Creating a potential for further development (development of innovative products for major stable or quickly growing markets (including emerging ones) in Russia and abroad; expected positive sales dynamics); and,
- Increased national security, including technological, environmental, power, food, and information security, while overcoming dependency on imported critical products and technologies.

Six expert groups were involved in the process of selecting new S&T priorities based on the S&T priority development areas identified in 2006.

The following aspects were taken into account when experts for the project were recruited:

- Bibliometric analysis of the candidates' scientific activities, reflecting their publication activity, citation index, and other characteristics;
- Participation in the largest projects (based on information provided by research foundations);
- Recommendations by the Russian Ministry of Education and Science, other government agencies, and the state Academies of Sciences;
- Representation of leading R&D centres and production companies; and,
- Co-nomination results.

[2] Approved by the RF Presidential Decree of 7 July, 2011, № 899.

A two-stage procedure was used to select priority development areas and critical technologies.

The first stage included preparatory steps and the development of analytical techniques and approaches for the project, including analysis of the following:

- Results of the long-term forecast of S&T development in Russia up through 2025;
- National socio-economic development objectives specified in programme documents;
- Results of the expert polling exercise conducted to make a draft list of innovative products;
- Suggestions to adjust the lists of priority development areas, critical technologies and key innovative products developed by federal executive agencies and the state Academies of Sciences.

A novel methodological aspect of the S&T priorities' selection process was the analysis of the long-term forecast results conducted using the Delphi technique under the supervision of the RF Ministry of Education and Science in 2007–2008, to identify potential demand for innovative products. The following indicators were used:

- The time of discovering the technological solution;
- The level of importance for RF;
- The overall impact (strengthening of positions on global markets, incorporation into global value chains, increased competition on domestic markets, contribution to solving social problems); and,
- The level of Russian R&D compared with the world leaders.

The analysis of the long-term forecast results revealed a potential demand for innovative products, including high-tech products and services. Russia's competitiveness on the global markets was assessed, and products in line with global S&T development trends were identified.

Subject areas and topics where R&D projects were scheduled to be completed through 2020 were seen as potentially innovative and in demand, and these were assigned high importance index values and top development level values.

Another significant methodological feature of the adopted approach was the consideration of the country's major socio-economic development goals when selecting S&T priorities. The list of these goals was drafted based on strategic documents outlining the prospects of economic and social development (various strategies, concepts, targeted programmes, etc.). Subsequently, the set of socio-economic goals and objectives was taken into account during the final selection of innovative products and critical technologies that could contribute to their accomplishment.

The second stage included various expert-based techniques and procedures, e.g. expert polling and expert discussions. Six expert work groups were set up, which have played key roles in selecting new priorities. Altogether, over 250 top-level experts were involved in the process, including employees of R&D organisations, universities, leaders of projects implemented in the framework of federal and departmental targeted programmes, representatives of industrial enterprises, members of the business community, R&D-supporting foundations, etc.

At the beginning of the second stage, initial lists of innovative products with a potential demand in future markets were drafted for all priority development areas; these were used to fine-tune and adjust priority areas and to select critical technologies. This work was done both in the course of expert discussions at work groups, and via expert polling of work groups' members and external experts.

The objective of these expert polls and discussions was to obtain additional information from a wider range of experts concerning the most important innovative products and services, and the technologies required to manufacture them. In the course of these expert polls, lists of existing innovative products/services were evaluated, and the most important (in the experts' opinion) innovative products/services were identified, which could be realistically expected to be developed in Russia (on the basis of the available R&D results) during the next 10 years. The experts received questionnaires asking them to assess the attached lists of products in terms of their comprehensiveness and, if necessary, to add new products.

In the course of expert discussions, a list of the most important innovative products/services (including high-tech ones) was drafted, the list of critical technologies available at the time was evaluated, and proposals to draft a new list of critical technologies based on the selected major innovative products were prepared. At the final stage, the experts assessed the descriptions of the critical technologies drafted during the expert discussions, and they amended the lists of the most important innovative products/service as they saw necessary. Then they assessed potential demand for them. In addition, data required for preparing technical specifications for the critical technologies was collected during the poll.

The exercise resulted in draft lists of priority areas and critical technologies, and in a list of major innovative products expected to be created in Russia in the next 10 years (based on the available R&D results) that are relevant to the country's socio-economic development goals. At the final stage, descriptions of the critical technologies were adjusted, and their technical specifications were prepared (including major parameters and conditions for their efficient development).

2. Obtained results

During the selection procedure described above, 8 new priority areas and 27 critical technologies were proposed (Table 2). Compared with the 2006 version, the list of critical technologies was reduced from 34 to 27 items. Five technologies retained their previous descriptions; 11 descriptions were somewhat modified, and the rest significantly revised. The new descriptions reflected the latest S&T development trends and the practical orientation of the priority selection procedure.

Table 2. Priority S&T development areas and relevant critical technologies

Priority areas	Critical technologies
Nanoindustry	Computer modelling of nanomaterials, nanodevices, nanotechnologies
	Nano-, bio-, information, cognitive technologies
	Nanomaterials and nanodevices diagnostics
	Nanodevices and microsystems
	Technologies for manufacturing and processing construction nanomaterials
	Technologies for manufacturing and processing functional nanomaterials
Information and telecommunication	Technologies providing broadband access to multimedia services
	Information, management and navigation systems
	Technologies and software for distributed and high-performance computer systems
	Technologies for creating component base and energy-efficient lighting devices
Life sciences	Bio-catalytic, bio-synthetic and bio-sensor technologies
	Biomedical and veterinary technologies
	Genome, proteome and post-genome technologies
	Cellular technologies
	Bioengineering technologies
	Technologies to reduce damage from socially significant illnesses
Rational use of nature	Technologies for monitoring and forecasting the state of environment, prevention and liquidation of environmental pollution
	Technologies for exploring, developing and mining natural resources' sites
	Technologies for the prevention and managing the consequences of natural and technological emergencies
Transport and aerospace	High-speed transportation vehicles and intelligent systems for operating and managing new types of vehicles
	New-generation rocket and space systems and transportation vehicles
Energy efficiency, energy saving, nuclear power engineering	Basic power electrical engineering technologies
	Nuclear power engineering, nuclear fuel cycle, safe handling of nuclear waste and depleted nuclear fuel
	New and sustainable energy sources including hydrogen power engineering
	Energy saving systems for energy transfer, distribution and use
	Energy-efficient power generation and transformation technologies based on organic fuel

In the medium-range term, one can expect scientific and technological breakthroughs in the identified areas, leading to the emergence of new markets, increased competitiveness of Russian manufacturers, a higher quality of life and better national security, i.e. they will have significant economic, environmental and social impact.

For each critical technology, technical specifications were prepared, describing its main use, characteristics and features, application areas, the current state of R&D, production potential, prospective developments matching or above the top international level, promising areas with the longest development lag, the most promising R&D results/experimental prototypes, engineering problems urgently requiring solutions, and leading Russian R&D and production centres.

For all critical technologies, major innovative products/services were identified, including their most important markets, the main impacts of relevant technologies, and special support measures required.

CTs correction is strongly linked with other foresight projects in Russia. For instance, as mentioned above, the results of the 1st cycle of long-term prognosis were used for the correction process. Furthermore, the identified list of PAs and CTs was used as a structure for the 2nd cycle of prognosis that helped to incorporate set priorities in the further forward-looking activity and improve our understanding of how this priorities can be realised. During this project, proposals for perspective research topics and large innovative projects that can be carried out in Russia were identified for every CT.

R&D in the selected priority areas and the development of the identified critical technologies are supported with a wide range of government S&T and innovation policy tools [10]. First, the RF government approved the federal targeted programme "Research and development in priority areas of developing Russia's S&T complex in 2007–2012" which was built around a lists of priority areas and critical technologies. R&D in the approved priority areas are also funded in the framework of other federal and departmental targeted programmes, including the following among others:

- "Russian federal space programme for 2006–2015,"
- "Development of electronic components base and radioelectronics,"
- "Global Navigation System" (Figure 1).

Based on the specifications of critical technologies, proposals to optimise tax breaks and preferences for R&D organisations are prepared. For example, in the area of "Bioengineering technologies," tax breaks are provided to companies conducting R&D in molecular, genetic, metabolic and protein engineering, including development of techniques for the identification of genetically modified organisms or the creation of highly productive transgenic forms of plants resistant to abiotic and biotic stress. Similar lists of subject areas have also been approved for all other critical technologies.

A lot of support to R&D in PA and the development of CT is provided through technological platforms. In particular, when such platforms were created, the participating organisations were careful to establish and maintain links between the platform's subject areas and the key areas of Russia's S&T development strategy.

Companies with public participation play an important role in supporting R&D in priority areas, because they develop innovative development programmes integrated into the overall priorities system of the government S&T and innovation policy.

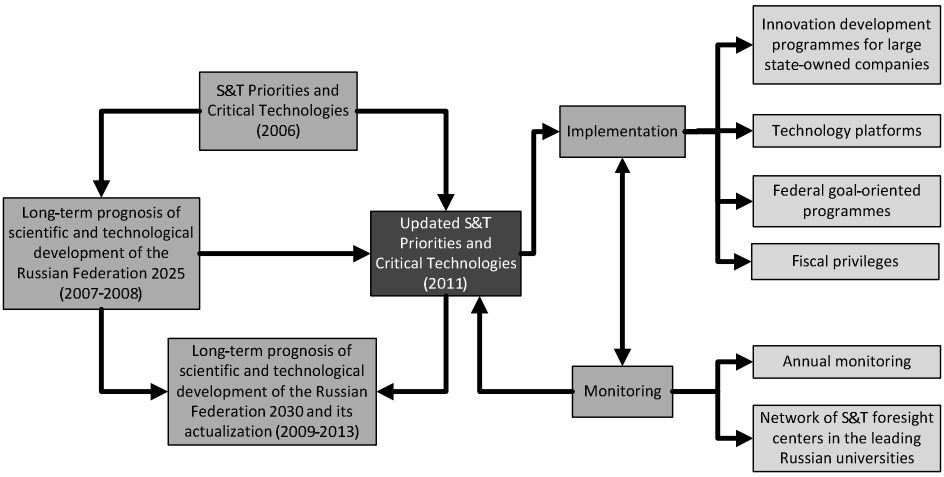

Fig. 1. System for selecting priority S&T development areas and critical technologies, conducting and monitoring relevant R&D in the Russian Federation

3. Monitoring R&D in priority areas and development of critical technologies

To collect up-to-date information about the impact of R&D in priority areas and the development of critical technologies, the RF Ministry of Education and Science in 2011 set up a monitoring system in the framework of a larger R&D economics monitoring effort. The monitoring results should improve the quality of information and the analytical basis for analysing and forecasting the development of S&T and innovation activities. The monitoring data will also be used to develop S&T and innovation policy and assess the efficiency of its various tools.

To the monitoring process, the following were engaged: federal government agencies, the state Academies of Sciences, companies with public participation which develop innovation development programmes, technological

platforms, public foundations for supporting R&D and S&T and innovation activities, and other organisations. All participants of the monitoring effort regularly submit information about their activities regarding the support of priority areas of R&D and the development of critical technologies. The information is submitted in several forms suggested by the RF Ministry of Education and Science.

R&D in priority areas and development of critical technologies are regularly monitored, using the following basic parameters and indicators:

- R&D expenditures;
- The number of completed R&D projects;
- R&D results obtained, and their importance for innovation processes and the modernisation of the Russian economy;
- Socio-economic impact;
- The number of projects implemented in the small, medium and large-scale entrepreneurial spheres;
- The number of patent applications submitted to Russian and international patent offices; and,
- The number of articles published in Russian and international reviewed journals.

At a later stage, there were plans to launch federal statistical monitoring of the development of critical technologies, according to a specially designed programme.

Monitoring of R&D in priority areas and the development of critical technologies will be conducted annually. The collected data will be used to update the lists of priority areas and critical technologies, which is done every four years.

In addition, on the initiative of the RF Ministry of Education and Science, a network of industrial S&T development-forecasting centres was established based on the leading Russian universities, for all six-priority areas. These centres' activities primarily include the monitoring of S&T development in the selected areas, relevant industries and sectors of the economy, followed by the production of analytical and forecasting materials.

According to the 2011 monitoring results, organisations' internal R&D expenditures on priority areas of R&D in 2010 amounted to $9.7 billion, or 56% of their gross internal R&D expenditures (GERD). More than half of the priority areas of R&D funding were allocated to finance R&D in the "Transport and aerospace" area. The lowest expenditures were made on R&D in the "Life sciences" area (5% of the GERD) (Figure 2).

In the course of the monitoring effort, particular attention was paid to R&D in priority areas and the development of critical technologies conducted by large companies fully or partly owned by the government-developed innovative

programmes. Such companies mostly fund R&D in the "transport and aerospace" and "rational use of nature" areas. The share of expenditures on "Life Sciences" R&D in their GERD is insignificant. This structure of expenditures is largely due to the profile of organisations.

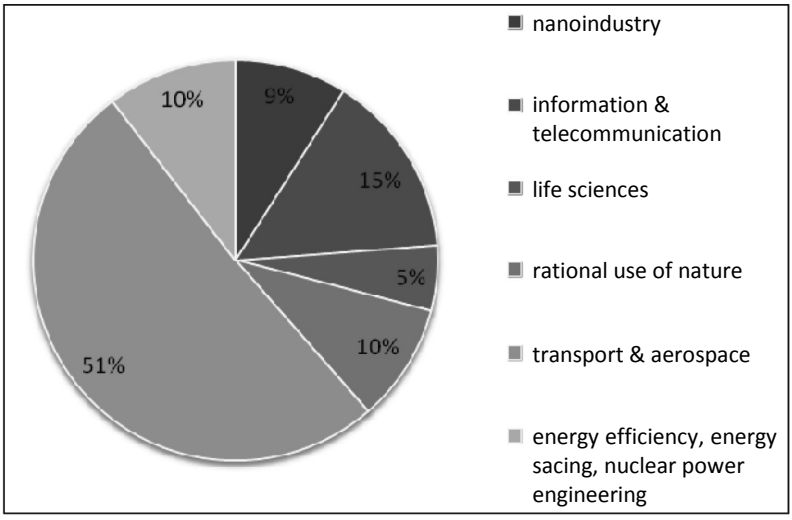

Fig. 2. R&D expenditures for PA in Russia in 2010

Organisations mostly finance development of the following critical technologies: exploring, developing and mining natural resource sites; new-generation rocket-and-space systems and transportation vehicles, the prevention and managing consequences of natural and technological emergencies, and information, management and navigation systems.

There is presently no data about the development of critical technologies in the framework of technological platforms, since they have been established just over a year and a half ago.

The monitoring data shows that, during the last two years, a number of R&D results were obtained in Russia in all priority areas, which are on *a par* with or above the top world level. In particular, several original and patented neuro-rehabilitation equipment prototypes, based on advanced aerospace technologies, were created. Major progress was made in the area of design, development, production, and clinical application of bio-polymeric materials to replace damaged soft tissues, which are also suitable for creating tissue-engineering constructions and for use as carriers for cellular transplantation. A spectral dynamic complex was created, which solves the problem of passive functional diagnostics of all organs and systems of the human body, offering sufficient accuracy (over 90%) and quick diagnostic results.

Conclusions

New lists of priorities allow us to focus the available resources on the areas that are expected to generate the strongest economic and social impact, and to improve the S&T and innovation government policy.

The current list of technologies is oriented towards the needs of the Russian business community and government agencies responsible for implementing S&T and innovation policy. It specifies technologies whose further development is strategically important for improving the competitiveness of the national economy, and new, emerging technologies that have a significant potential in Russia.

The selected S&T priorities are already being used in the framework of a number of initiatives to develop the national innovation system, including technological platforms, companies fully or partly owned by governmental developing innovative programmes and innovative territorial clusters.

The suggested approach allowed bringing S&T development priorities closer to the actual needs of the economy and society. The transparency of the priority selection procedures should also be noted.

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Reviewer:
Alexander CHULOK

Kluczowe technologie w Rosji: identyfikacja i wdrażanie

Słowa kluczowe

Prognozowanie długoterminowe, foresight, technologie kluczowe, priorytety naukowo-technologiczne, monitoring.

Streszczenie

W Rosji, począwszy od roku 1996, opracowywane są i regularnie aktualizowane listy priorytetów badawczych i kluczowych technologii, stanowiące istotne narzędzie zarządzania procesem opracowywania innowacji. W wyniku przeprowadzonej w roku 2011 aktualizacji zatwierdzono nową listę obejmującą 6 kierunków priorytetowych i 27 kluczowych technologii. W artykule przedstawiono analizę stosowanych podejść do opracowywania i aktualizowania list technologii kluczowych, ze szczególnym uwzględnieniem zastosowanej metodologii. Szczególną uwagę zwrócono na spójność pomiędzy prowadzonymi badaniami i długoterminowymi projektami typu foresight. Ponadto zaprezentowano zagadnienia związane z praktyczną aplikacją wysoce priorytetowych i kluczowych technologii oraz przeanalizowano możliwości opracowania systemu monitorowania procesu wdrażania tego typu rozwiązań.