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# LONG-TERM SCIENCE AND TECHNOLOGY POLICY – RUSSIAN PRIORITIES FOR 2030

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# LONG-TERM SCIENCE AND TECHNOLOGY POLICY – RUSSIAN PRIORITIES FOR 2030

Currently the framework conditions for science and technology and innovation (STI) policy have changed significantly in Russia: a system of technology forecasting has been established, which focuses on ensuring the future needs of the manufacturing sector of the national economy. This system was supposed to be the main part of the state strategy planning system which is currently being formed. Over the last decade dozens of science and technology forward-looking projects have been implemented, among which 3 cycles of long-term S&T Foresight stand out prominently. The Foresight was developed by the request of the Ministry of Education and Science of the Russian Federation. The development of the 3rd cycle of long-term Foresight includes both normative («market pull») and research («technology push») approaches. The project involved more than 2,000 experts and more than 200 organizations. Within the project a network of six sectoral Foresight centers was created on the basis of leading universities. The article describes the most important issues of future studies in Russia and presents the principles which formed the basis for the long-term science and technology (S&T) Foresight until 2030. The authors explore its position in the national technology Foresight system and the possibilities for the implementation of its results by the key stakeholders of the national innovation system and on the level of STI policy. Eventually Russian experience could be fairly interesting and useful for many other countries with similar socio-economic features and barriers.

JEL Classification: O31, O32, O33, O38, O21, O25, O43.
Keywords: Foresight, Russia, research and development strategy, planning of science and technology development, Russian technology Foresight system, innovation policy.

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## 1. Introduction

In the recent decades a major S&T development trend in leading countries across the world was the quest for new approaches to shape the science, technology and innovation (STI) policy, particularly by setting priorities for allocating R&D funds, and making informed strategic decisions in the light of those priorities. Among these efforts, special emphasis was given to applied R&D, which creates future-oriented S&T impacts – and thus serves as a “bridge” between basic research and industrial technologies.

Applied research has a great role to play in dealing with Grand Challenges, which the society and economy are expected to face in the medium to long term. Grand Challenges require integrated and interdisciplinary efforts responses [European Commission, 2010c]. In this respect, applied research is expected to make an immense contribution in a number of areas, such as the depletion of strategic mineral resources; discovery of alternative energy sources, and ensuring energy safety; tackling with the ageing society and changing lifestyles; fighting against diseases; creating “green economy” towards a “post-carbon” society; developing novel economic growth models; and exploiting new and emerging technologies, which is accompanied by a radical change of the industrial structure and other factors, which determine competitiveness.

Setting long-term priorities for applied research creates a foundation for future economic growth; determines the opportunities for entering prospective markets while creating new ones; and provides a basis for technological modernisation of various sectors of the economy and for generating much-needed skilled and competent labour force for these transforming systems [Meissner et al., 2013].

The aforementioned activities have significant importance for the development of the Russian innovation system, which inherited a historically developed gap between R&D and business with a depletion of the pool of successful future-oriented S&T studies generated during the Soviet period [Gokhberg, Kuznetsova, 2011]. In this respect, the idea of supporting a coordinated programme in applied research emerged with the aim of creating and accumulating a critical mass of successful S&T applications with implications for the strategies to achieve those outcomes to be implemented by the government, state-owned companies and all other relevant stakeholders.

Today the Russian Federation sets an ambitious goal of moving into the “premiere league” of more advanced economies with higher living standards for their population. There is a greater awareness that this ambition cannot be realised within the framework of the current “resource-based growth model" which is prone to exhaust itself [the RF President’s address to the Federal Assembly, 2012]. A twofold objective will have to be accomplished, which requires both breakthroughs in the development of global high-technology markets and modernisation of the traditional sectors of the economy. Obviously, Russia's future positions in the global value chains largely depend on whether the Russian economy would be able to successfully fit into the new wave of technological development, which, according to certain indicators, has already started [Perez, 2011]. This, in turn, requires concentrated effort by all key players in business, R&D, government, education, and other societal actors.

The above determines the importance of identifying long-term development priorities on the basis of an integrated approach, taking into account both the external framework – global trends, challenges, and windows of opportunity – and the internal strengthts and weaknesses. Identification of research areas with the largest potential to contribute to building a prosperous economy for the future is one of the key objectives of the national long-term foresight of S&T development, commissioned by the Ministry of Education and Science of the Russian Federation to the National Research University – Higher School of Economics [Sokolov, Chulok, 2012].

## 2. Foresight in the field of science and technologies: key tendencies

### 2.1 Global Foresight activities

The first attempts for systematic forecasting of long-term S&T development tendencies technology go back to the 1950's[4]. Since then, hundreds of projects have been carried out in different countries, aimed at estimating the future of science and technologies. This process has been especially active in the last 10-15 years. Foresight-researches provide a basis for setting priorities, which define the activities undertaken within the framework of large scale national and international STI development programmes. Based on these researches, technological modernization plans for big companies are made, and the prospects for technological development within certain sectors of the economy are being discussed. Nowadays, Foresight has transformed from an instrument, aimed at identifying technological trends, into an independent, actively developing scientific discipline, covering a wide spectrum of research methods.

In the last several years, S&T Foresights help reveal a number of important tendencies. This fact which reflects both progress in the methodology of such research and a deeper understanding of the processes of innovation development, as well as significant complication of S&T mechanisms and innovation policy. Luke Georghiou reflected these tendencies as five generations of Foresight [*Georghiou et al.*, 2009, pp. 15–16]: while in the initial stage, the role of the forecast was limited mainly to delivering information to decision makers regarding the internal development dynamics of science and technology (1$^{st}$ generation), the later types of forecast-researches cover a probable

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[4] The RAND Corporation in these years started researches of the development prospects in the sphere of security. The Delphi method, in particular, was developed there [*Dalkey, Helmer-Hirschberg*, 1962].

input, which the science provides in resolving certain economic and social problems (2nd); wider social estimation and analysis of the development prospects of alternative institutions (3rd); coordinated interdisciplinary assessment of the future of science and innovations (4th); and finally, the development prospects of the structures in the national innovation system (NIS) and the scientific and technological aspects of the socio-economic development as a whole (5th). In such a way, we can clearly trace the tendency of change in the role of Foresight-researches, starting with merely informational functions up to full - as much as it is possible - integration into the process of forming and foregrounding scientific-technological policies.

The emerging of new, more complex instruments of S&T policies, (which take into consideration the interests of different players (stakeholders)[5], and the transformation of the nature of innovation itself, due to the enhancement of the role of non-technological innovations, the expansion of the open innovations model, etc.), puts on the agenda of Foresight-researches' nontrivial tasks. These tasks include the identification of characteristics and, restrictions for usage of certain policy instruments, as well as the formulation of approaches to evaluate their potential impact on the sphere of science and innovation, the economy and the society. On the one hand, in the conditions of forming a systematic strategy of supporting the innovative development, Foresight is called upon to provide the decision makers with the information regarding the possible scenarios and future forms of the NIS. On the other hand, the technological and innovational policy itself is subjected to serious changes. Among its tasks for medium and long-term prospects, we can point out: the development of the innovational potential of human resources (work force, innovations' consumers, development of the entrepreneurship culture and others), the lowering of barriers for innovational activities, contribution to the processes of establishment and practical exploitation of knowledge, the appliance of innovations to meet Grand challenges, and - of course – enhancement of the policy effectiveness in the sphere of science and innovations [OECD, 2010, pp. 215–216].

With the complication of the Foresight tasks, a paramount importance is given to the consideration, within its framework, of certain problems, which at first glance fall far beyond the scope of the narrow understanding of the sphere of science and technology. On account of this phenomenon, we witness an integration of the scientific-technological Foresight into a much wider circle of researches of the future (Forward Looking Activities, FLA [European Commission, 2010]),which nowadays have become a standard practice, for example, in the process of policy formation of the European Commission. Great significance is given, in this regard, to the Foresight

[5] The Organization for Economic Co-operation and Development (OECD), plays a major role, in that sense, by actively "promoting" conceptions of consolidating governmental efforts (whole-of-government policy framework) and integrating various policy instruments (policy-mix) [OECD, 2010].

as an instrument of developing long-term visions of the future, identifying probable disruptive events[6] and assessing the effect, which the implementation of certain policies will have.

Among the FLA instruments we find some widely known Foresight methods (such as road maps, priority setting, constructing visions of the future), as well as some relatively new approaches (such as weak signals and wild cards[7]). Special attention is given to the integration of the numerical forecasting methods and judgment-based methods[8]. An important factor of such integration is the rapid progress of the Internet, which makes powerful instruments of "smart" search as well as quantitative and qualitative analysis of expert data accessible to the public. At the same time, the use of expert knowledge allows us to significantly raise the accuracy of traditional forecasting models, which are rapidly going out of date in the reality of the accelerating S&T dynamics. This process is determined by the expansion of the circle of variables under analysis and by the introduction of quantitative parameters, which make it possible to bring the models much closer to reality.

A special focus of the Foresight-research agenda is the detection and analysis of large-scale in significance Grand Challenges – far reaching and very complicated problems already encountered by the mankind, the influence of which, in the medium and long-term prospects is expected to strengthen[9]. They are of an interdisciplinary character and require coordination of actions taken by various authorities on all levels – from the international to regional level. The role of Foresight in this regard amounts not only to, and not even mostly to identifying these Grand Challenges, but to looking for Grand Responses, -- the necessary instruments and policies, which will contribute to resolving these problems in the most effective way. Taking into consideration the complexity of the latter, a systematic understanding of S&T development priorities has been outlined. While in earlier days it dealt primarily with thematically separate S&T spheres, which were to get the advantage when relevant resources were being allocated, nowadays Foresight-researches emphasize other systematic goal oriented indicators. These includepriorities on the macro level, and are determined by some external to the field of science and technology conditions

[6] About the theory of disruptive innovations see [*Christensen*, 2004].

[7] Wild cards - events of low probability, capable of radically changing the situation in a certain field. For more details on the approaches to the relevant researches see the article by V. van Ray in the current journal issue [*van Ray*, 2012], and [*Popper*, 2011].

[8] At the largest international conference on technological forecasting (Future-oriented Technology Analysis - http://foresight.jrc.ec.europa.eu/fta_2011/intro.html) one of the three thematic sections was dedicated to this topic [*Haegeman et al.*, 2012].

[9] Much attention is given to this notion by the European Commission when forming the systems of Foresight projects, which are carried out according to the 7th Framework Program for research and development. See more about the role of Foresight in analyzing grand challenges in [*Amanatidou*, 2011; *Cagnin et al.*, 2012].

(political, economic and social conditions[10]); functional priorities, which arise as a result of the necessity to develop the NIS institutions; and the S&T priorities themselves.

The integration of Foresight into the process of working out the STI policies provides a basis for elevating its contribution to the effective work of the NIS. More specifically, Foresight can act as an instrument of “strategic intelligence” [Calof, 2008] on account of its analysis of long-term S&T trends, forecasting the development of research fronts, which appear at the interface of their traditional spheres. Moreover, Foresight can contribute to the appearance of new knowledge and its “diffusion” by means of discussion with a wide circle of stakeholders, who, due to this, can better know their way around, when choosing modes of behavior and lines of activities. Cagnin, Amanatidou and Keenan [Cagnin et al., 2012] emphasize particularly the role of Foresight in the identification of new markets (through articulating the relevant technological prerequisites), and in forming new combinations of interactions between the NIS actors and their mobilization to the reallocation of resources.

## 2.2 Foresight practices in Russia

In the last several years, Russian STI policies have undergone some significant changes, which primarily concern the expansion of the circle of its subjects and the spectrum of the instruments used. It is worth mentioning the initiatives to support national research centers and research universities, cooperation of academic institutions with enterprises from the real sector of economy, recruitment of leading scientists to Russian academic institutions, development of the innovation infrastructure of the academic institutions; forming programs of innovative development for companies with the participation of the government, technology platforms, territorial innovation clusters; creating a “line” of development institutions (including Skolkovo, Russian Venture Corporation and others) — these measures indicate the scope of transformations.

At the same time, a gradual shift can be outlined in the work of the R&D support system– from “best among the existing ones” to “best among what is needed” and as a result we see the enhancement of the demands to concentrate budget financing on a limited amount of key areas. Obviously, identifying the related priorities and establishing the criteria for their selection, one needs to perceive the “big picture” of the future; take into consideration the Grand challenges and windows of opportunities, hidden technological wild cards and the S&T capacity potential. Such a level of complexity requires conducting technology forecasts on the national level and involving

[10] Thus, in the European Union program “Europe 2020” three integral goals are pointed out: “smart growth” – forming-up an economy based on knowledge; “sustainable growth” – developing a resource efficient “green” economy); “inclusive growth” – increasing employment, strengthening international and social solidarity within the society. [http://ec.europa.eu/growthandjobs/pdf/complet_en.pdf].

key stakeholders and experts (in all the priority areas of S&T development and in various sectors of economy) in the result forming process. The experience of many developed and developing countries[11] indicates that Foresight is one of the most effective instruments to accomplish this kind of tasks by providing coordination of the positions of different players in regard to a common goal, in the conditions of uncertainty in the external and the internal situation and multidirectional interest vectors.

In Russia, during the last decade, a significant growth is witnessed in the number of projects which are carried out on the basis of the Foresight methodology, and the scope of financing of some of them has reached the level which is commeasurable to its compatibles in the developed and the leading developing countries. It is worth mentioning, that while at first, the initiative came mostly from the top level – i.e. the governments (represented by federal ministries and authorities, development institutions etc.), nowadays enhanced activity is witnessed on the regional level – mainly in industrially developed regions and cities around Russia, such as Moscow, Yekaterinburg, Samara region, Republic of Bashkortostan, Krasnoyarsk Krai, Sakha Republic (Yakutia) and others. A significant number of technology forecasts are carried out by big companies as part of working out their strategies and plans for innovative development.

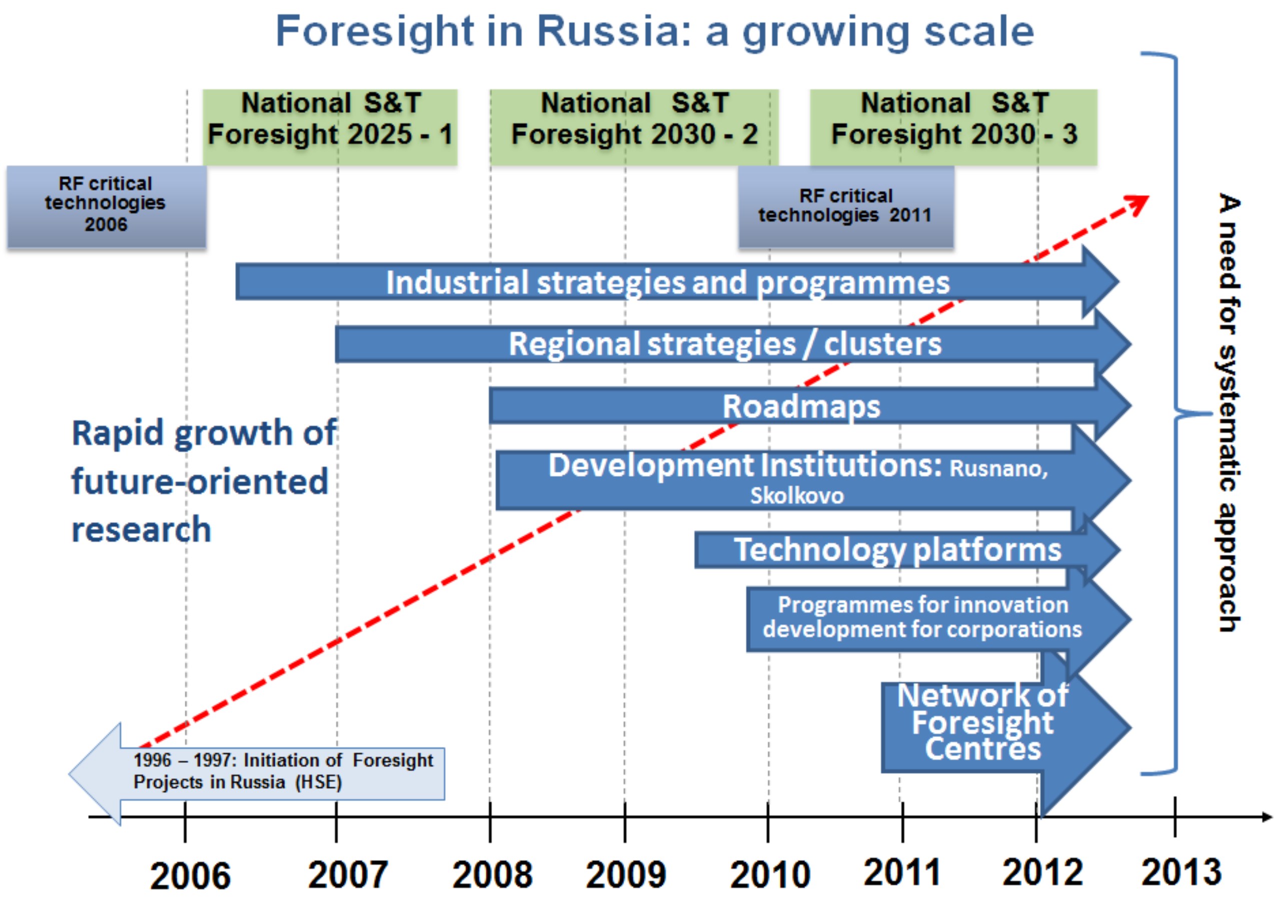
However, the analysis of the available information on Russian Foresight-researches shows that many of them are not in fact Foresight and that they only use the brand to attract resources and build a respectable image for their projects. In many projects, some key characteristics of Foresight are either completely absent or presented in a strictly formal way – including such important characteristics as the involvement of all stakeholder categories and highly qualified experts, implementation of a solid proof basis, organization of a creative interaction between the experts, discussion of the obtained results with a wide circle of concerned parties. This problem requires a separate discussion and analysis, as the spreading of “pseudo Foresight” creates unjustified illusions with the ordering parties, generates warped conceptions of the methodology and the results of the researches, and eventually leads to an impeachment of the term “Foresight” itself. Profanation of Foresight is less common in the field of science and technology, seeing that the forecasting in this sphere has a more systematic and particularized character and the research is usually based on involving a large number of highly qualified experts.

In diagram 1 you can see the information regarding the most significant STI Foresight-projects which were carried out in Russia in the last several years. In this picture, though it is not complete, one can see how actively the Foresight culture has penetrated the various levels of

[11] More than 150 Foresight-projects, which were carried out in different countries, are presented on the European Foresight Platform website (www.foresight-platform.eu).

administrative decision making – national, regional, industrial and corporate. We believe that this allows us to talk about the accumulation in Russia of a "critical mass" of projects, experience and motivation to move up to a new level of goal setting and quality of research results that is correspondent to the modern Foresight rhetoric[12]

**Diagram 1. Russian Foresight-projects in the sphere of science, technologies and innovations**

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[12] The prerequisites for this process were discussed by Michael Keenan already in 2007 [*Keenan*, 2007].

The first attempts to apply S&T Foresight in Russia go back to the 1990's, when a preparation of the first lists of critical technologies was initiated (for more details see [Nikolayev, 1995]). However, at that time the set of methods which could be used was quite limited, and the implementation of the obtained results was not one of a systematic character. The first example that can be regarded a full-scale Foresight-research is the 1998 Delphi survey, which involved more than a 1000 Russian scientists and experts [Sokolov, 1999; Denisov, Sokolov, 1998]. This project, assigned by the Russian Ministry of Science attempted to evaluate the long-term S&T development prospects, and to determine the fields of knowledge which require immediate support from the government. The obtained results indicated the necessity of the correction of S&T policy priorities with due account for the As-Is State of the Russian science in its various lines of activity.

In the following stages, the formation of the national S&T priorities was carried out with a more solid systematic basis and within a unified methodology[13]; the results were approved by the President of the Russian Federation in a form of lists, prioritizing the different lines of development in science, technology and engineering and critical technologies for the Russian Federation[14].

The first large-scale Foresight-project on the national level was the long-term forecast for S&T development in Russia for the period up to 2025, initiated in 2007 by the Russian Ministry of Education and Science. It included three large sections: *macro economic forecast for* the Russian economy; S&T *forecast* (in seven prioritized fields); and *industrial forecast*, the purpose of which was to work-out options for possible technological development of the top-priority sectors of the economy[15]. One of the main elements of the first cycle of S&T forecasting, was conducting a large-scale Delphi survey, which covered more than two thousand experts from leading scientific organizations, academic institutions and innovative companies, representing more than 40 Russian regions. As a result more than 800 technologies from ten thematic scientific fields were pointed out; later a survey was held among 100 largest companies in Russia, in the leading sectors of the Russian economy, and an analysis of the current and prospective demand for such technologies was carried out.

Within the framework of the second cycle of S&T forecasting (2008-2009), in addition to the three sections mentioned above, foreign and international forecasts in the field of the economic and S&T development were analyzed, and on this basis, evaluations were made regarding the future of the global economy and certain large world markets. The obtained results were then used in the macro-economic forecast, within the framework of which, scenario options were revised regarding

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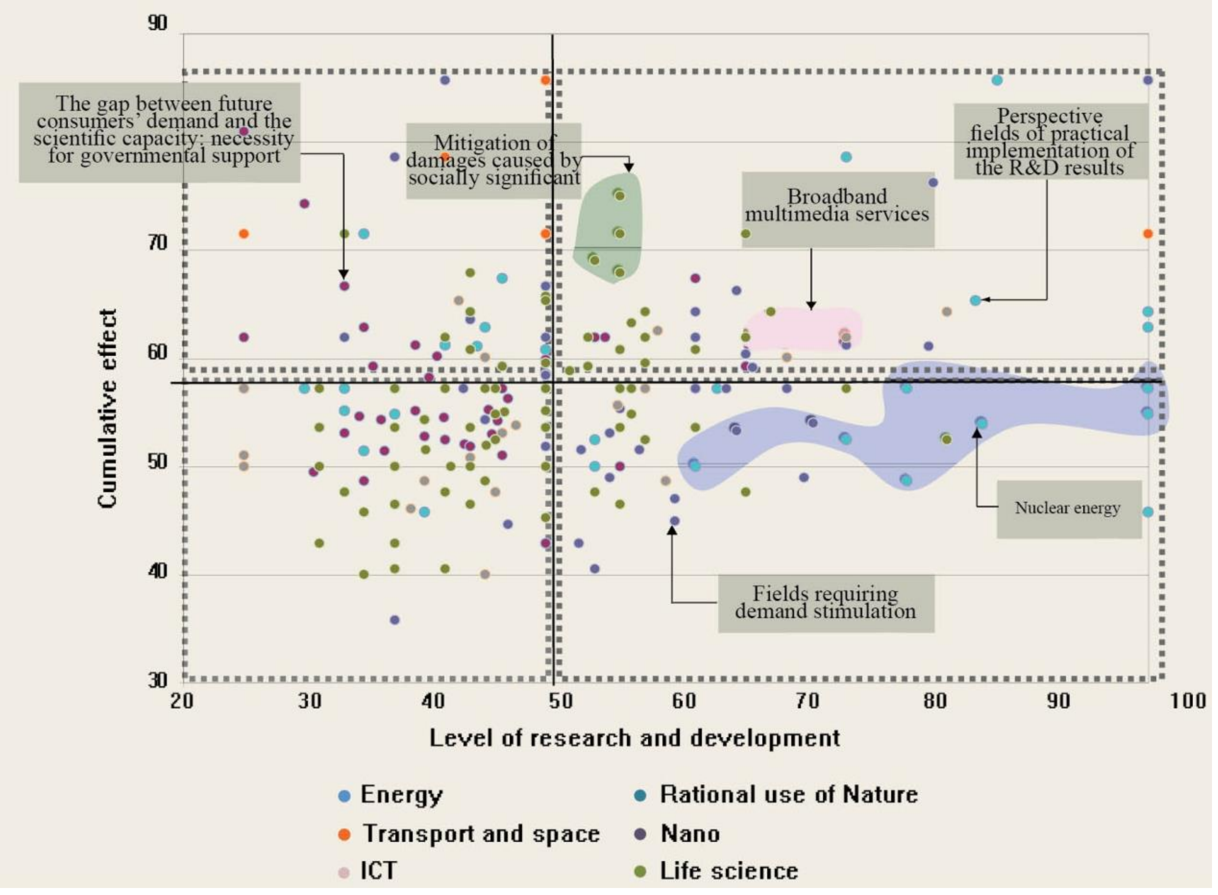
[13] To learn more about the method of critical technologies and its history of implementation in Russia, see [*Sokolov*, 2007].

[14] The current list had been approved by a Russian Federation Presidential Decree №899 dated July 11$^{th}$ 2011.

[15] The results of this cycle of scientific-technological forecasting are described in details in the articles [*Apokin, Belorusov*, 2009; *sokolov*, 2009; *Chulok*, 2009].

the dynamics of the Russian economy with due consideration of the development prospects of world markets and the expected repercussions of the global financial and economic crisis. In the course of expert research, clusters were defined, which covered the prospective technology groups and products, which were later analyzed in view of the achieved level of R&D in Russia and the potential socioeconomic effect (diagram 2).

**Diagram 2. The second cycle of S&T forecasting: evaluation of the development prospects of technology fields**




As part of the expansion of work in the field of national S&T Foresight under the auspices of certain government offices, national corporations and other organizations, a series of projects were carried out, aimed at evaluating the fields of innovation development in such sectors as Information technologies, natural resource management, power engineering industry [*Dub, Shashnov*, 2007], atomic power and others.

A large-scale project, which was ordered by the government-owned corporation "Rosnanotech" is worth mentioning in particular; within the framework of this project a Delphi survey was carried out, which reflected the prospects of using nanotechnologies in different sectors, and detailed road maps were developed [Karasev, Sokolov, 2009; Karasev, Vishnevski, 2010].

## 2.3Assessment of previous global and Russian experience

All of these researches have contributed, at some level, to the formation of a multipronged vision of S&T development prospects in Russia. However, the main role in this process undoubtedly belongs to the long-term foresight for S&T development, which is carried out under the auspices of the Russian Ministry of Education and Science. The evolution of forecasting reflects a progress in the understanding of the Foresight tasks, the depth of the developed methodical approaches and the enhancement of the expert base (table 1).

**Table 1. Evolution of approaches towards S&T forecasting in Russia**

| Field | Cycle I | Cycle II | Cycle III |
|---|---|---|---|
| International | • Evaluation of international key tendencies and challenges<br>• Analysis of foreign Foresights and forecasts, international methods | The emerging of a special section, which shows the correlation between the Russian results and the foreign Foresights and forecasts | • Evaluation of the Grand challenges for S&T development<br>• Forming a specialized expert panel which includes leading foreign Foresight specialists for the validation of the project's results |
| Macro-economics | Formation of a basic macro-economic scenario forecast for economic development | • Working out a macro-economic forecast with due account for crisis phenomena in the economy<br>• Establishing a system of demands for modernization processes in the key sectors of the economy according to the macro-economic scenarios | • Evaluation of S&T development in the context of global civilizational cycles<br>• Adjustment of the macro-economicforecast with regards to the interconnections between the parameters of socioeconomics and science and technology |
| Science and technology | Carrying out the first round of expert survey using the Delphi method, forming a list of 900 prospective technologies in ten development fields of science and technology | Carrying-out the second Delphi round, identifying clusters of the most important technological groups, determining the lists of prospective products in 6 extended development fields of science and technology | • Adjusting the structure of the 6 extended development fields of science and technology, determining the prospective technological packages, aimed at resolving the key socioeconomic problems, identifying the breakthrough innovative products and technologies<br>• Preparation of a series of Road maps for innovation in key thematic fields in ICT, |

| Field | Cycle I | Cycle II | Cycle III |
|---|---|---|---|
| | | | biotechnologies, nanotechnologies |
| Fundamental research | Preparation of a forecast for the development of fundamental researches within the framework of an independent project of the Russian science academy | | Forecast for the development of fundamental researches emphasizing the prospects of its practical appliance and identification of improvement centers in Russia |
| Sectors of the economy | In 6 key sectors of the Russian economy: analysis of the tendencies for long term development, forecast for the prospective demand for technologies and technological solutions | In 10 key sectors of the Russian economy: determining the shape of things to come, working out development scenarios, forming a list of process and product technologies for each scenario | Preparation of road maps for the innovative development of several sectors of the Russian economy |
| Infrastructures | Working out suggestions for the appliance of the Foresight method within the framework of regional development strategies / strengthening the competitive abilities of the regions | Working-out recommendations for pilot regions on the appliance of the scientific-technological Foresight results in readjusting regional strategies (Saint-Petersburg, Khanty–Mansi Autonomous Okrug) | The emerging of a special section in the project, concerning the establishment of a forecasting network for the selected fields of science and technology |
| Human resources | Forecast for the scientific potential resource requirements | A quantitative forecast for required competences according to the fields of science | Forecast to analyze the demand for certain competences / high-skilled specialists |
| Policy recommendations | • Forming a Foresight conception<br>• Working out suggestions for improving S&T policies, in a way | • Suggestions to integrate Foresight into the strategic decision making system<br>• Recommendations to readjust the | • Evaluation of the efficiency of S&T development based on a unified forecast calculation system<br>• Forming a methodological base for the unified |

| Field | Cycle I | Cycle II | Cycle III |
|---|---|---|---|
| | that will provide the necessary conditions for the implementation of the results of the completed forecasts | existing S&T policy instruments in the light of the economy crisis | S&T forecasting system Suggestions for the use of the road maps instrument when forming and carrying out governmental policies in the sphere of science and technology |
| International classification by five generations of Foresight[16] | Closer to the first three generations, which are characterized by their orientation towards S&T analysis, market evaluations, technologies, macro-economical aspects | Closer to the fourth generation, oriented towards creating the conditions for integrating Foresight into the decision making system and the national innovation system | Closer to the fifth generation of Foresight, which is characterized by a strong orientation towards supporting administrative decision making by the same parties, which implement S&T policies |
| Similar foreign projects | Japanese Delphi, British Delphi[17] | FUTUR Program (Germany) – www.futur.de | Foresight programme of the Ministry of Science and Technology in Great Britain (www.foresight.uk) |

[16] See above the part about classification, offered by L. Georghiou (Georghiou et al, 2009).
[17] See respectively: [NISTEP, 2010; *Loveridge et al.*, 1995; European Commission, 2006].

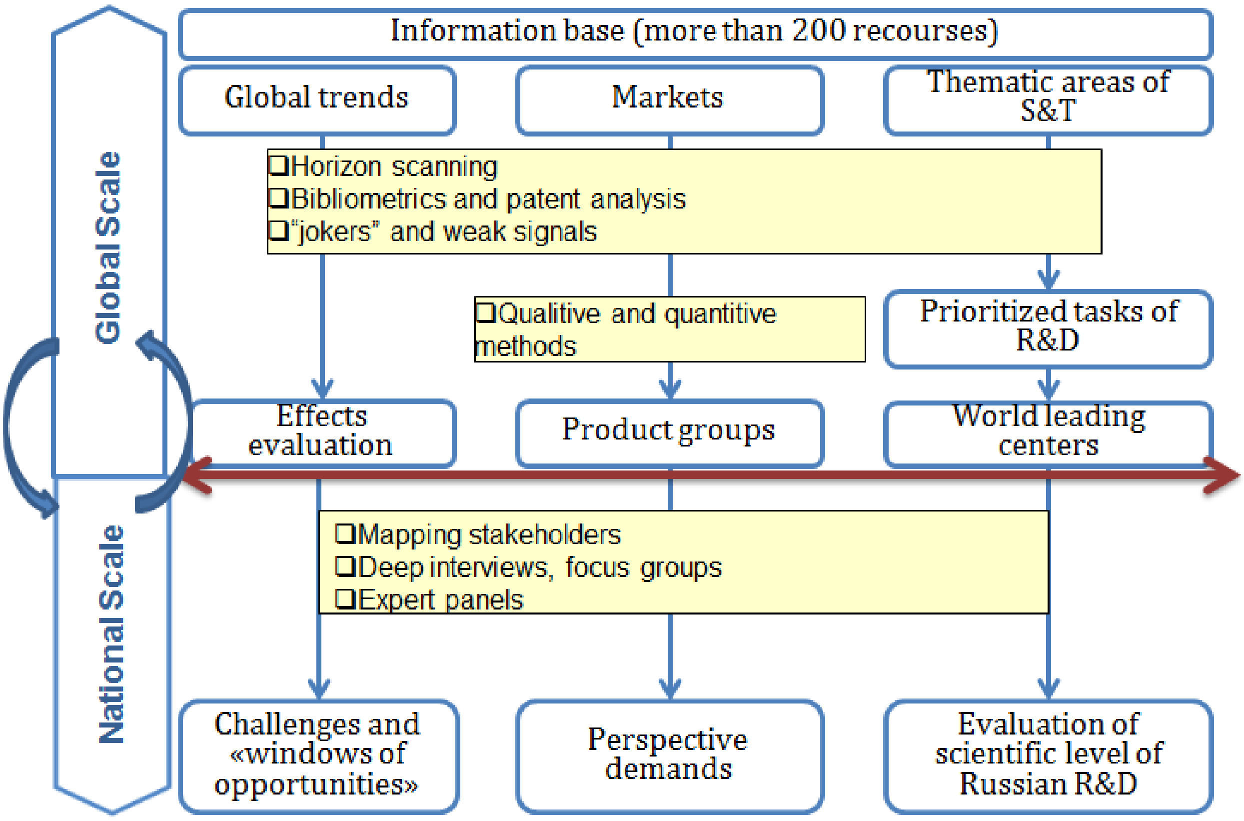
## 3. Methodology and Approach - Goals and tasks for the third cycle of the Russian scientific-technological Foresight

### 3.1 Objectives, goals and main principals

Understanding of the future of the key sectors of the economy, along with the lists of fundamentally new (breakthrough) innovative products (in the cross section of technological fields which generated them) established as a result of the second cycle of the abovementioned forecasting. , It served as a foundation for the launch of the *third cycle of work*, which began in 2011. The goal of this project is the identification of the most prospective for Russia fields of S&T development and implementation in the long term; technologies and technological solutions, which can provide realization of competitive advantages of the country, in view of grand challenges and opening windows of opportunities.

In comparison with the previous cycles of Foresight, this particular research is different both in its more complicated and comprehensive structure, which covers 16 participating organizations, and in its deep elaboration of the general concept. The scheme of organization of foresight is depicted on the diagram 3.

**Diagram 3. Scheme of organizations of the third cycle of the Russian S&T Foresight**




*Source: HSE*

Long-term S&T Foresight was based on the application of a wide range of advanced Foresight tools, which were, on the one hand, most adapted to the specifics of the Russian economy and, on the other hand, proved to be effective in international practice. Within this Foresight normative («market pull») and research («technology push») approaches to forecasting were integrated and implemented. The normative approach had a task-oriented (market) nature, which means that the key issues, challenges and «windows of opportunity» are first identified in the selected S&T areas. Then appropriate solutions in terms of «technology packages» or other responses to the challenges and problems are prepared. The approach helped identify promising products and breakthrough technologies that could fundamentally change the existing economic, social and industrial paradigm. Recommendations suggested in S&T Foresight 2030 were formed simultaneously according to three positions – markets, technologies and management that allowed (within the dialogue between different groups of beneficiaries) not only to identify promising S&T areas, but also to understand who and how one will be able to utilize results of their development.

Among the basic set of tools used in Foresight there are both traditional methods (priority setting, construction of images of the future, road maps, analysis of global challenges) and relatively new approaches (horizon scanning, «weak signals», «jokers», etc.).

The work presupposed systematic understanding of the priorities of S&T development, defined not only by the dynamics of development, but first of all by the necessity to address critical social and economic problems.

Sources of information for the realization of Foresight:

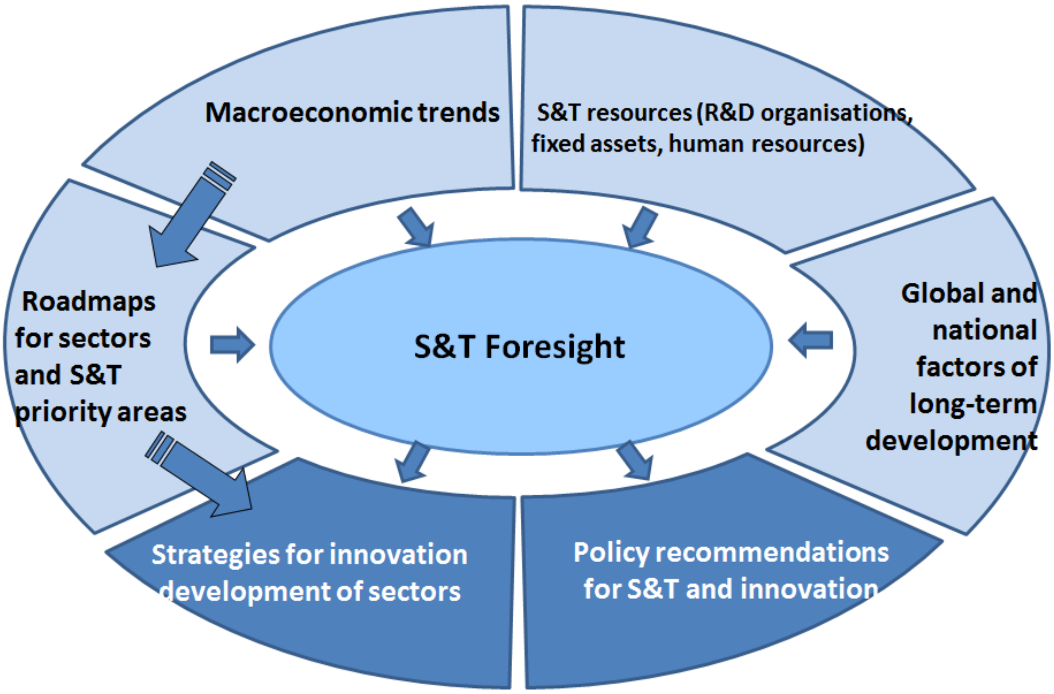
- analyses and forecasts of international organizations (OECD, European Commission, United Nations, UNIDO, World Bank, World Health Organization, OPEC and others);
- national Foresights of science and technology (United Kingdom, Germany, France, USA, Japan, Korea, China, Finland, the Netherlands, Taiwan, etc.);
- Foresights of large corporations (Shell, BP, Siemens, Microsoft, Daimler, Deutsche Bank, etc.), as well as a number of international professional associations;
- materials from leading international Foresight centres (RAND Corp., The Institute for Prospective Technological Studies EU, University of Manchester, National Institute of Science and Technology Policy of Japan, Telfer School of Management - University of Ottawa, Korea Institute of S&T Evaluation and Planning, Georgia Institute of Technology, Institute of policy and Management of Chinese Academy of Sciences, Austrian Institute of Technology, and others);
- Russian Foresights in the field of science and technology, including implemented through the request of the Russian Ministry; strategic documents that reflect the long-term prospects of the Russian economy and

its sectors (The concept and long-term forecast of socio-economic development, industry strategies and the development of innovative software companies, etc.);

- databases of patent services (Rospatent U.S. Patent Office - USPTO, the European Patent Office - EPO, the World Intellectual Property Organization - WIPO, etc.);
- databases of international journals (ISI Web of Knowledge of Thomson Reuters, Scopus of Elsevier company, Russian Science Citation Index, etc.).

In diagram 4 the conceptual paradigm of the third cycle of the Russian S&T Foresight was drawn up.

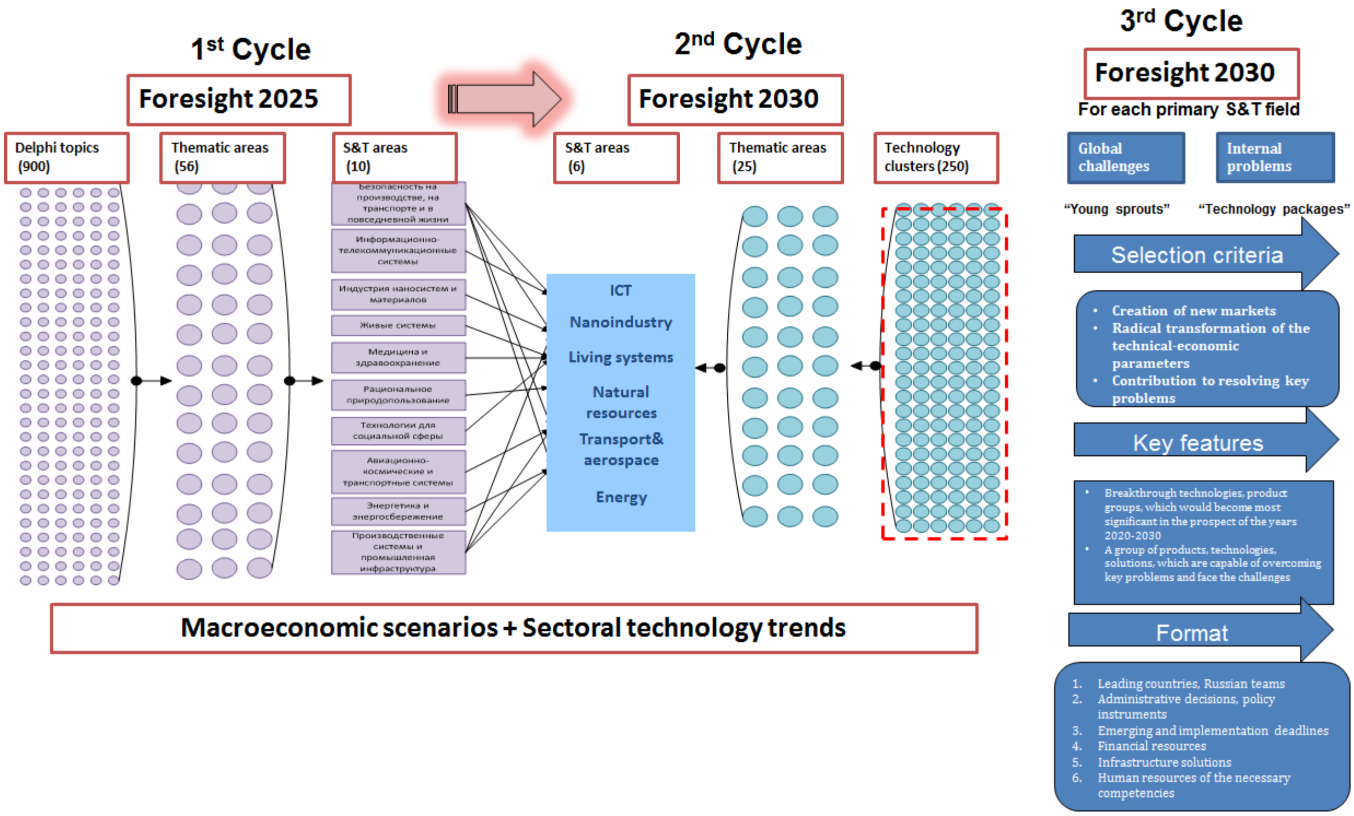
**Diagram 4. Conceptual paradigm of organizations of the third cycle of the Russian S&T Foresight.**




The current round of S&T Foresight, which we are now dealing with, stipulates for *a combination of both investigatory* (“technology push”) *and standard* (“market pull”) *approaches to forecasting*. In turn it requires, first of all, searching for products and technologies with a breakthrough character, which are capable of changingthe existing manufacturing and economic paradigm at the grassroots level (sort of “young sprouts” in the existing technological “field”). Secondly, it requires implementing a problem-oriented (market) approach, within the framework of which one has to determine the key problems, challenges and windows of opportunities for the selected S&T fields, and then find the corresponding solutions in terms of “technology packages” or other responds to the established challenges and problems (diagram 4).

Each of the planned results needs to be characterized in at least three aspects, in particular from the points of view of the markets, technologies and administration. Eventually it will be possible to establish interconnections with different groups of consumers for these results, and provide answers not only to the question “what?”, but also to the questions “for whom?” and “how?”.

**Diagram 4. Evolution of approaches to the evaluation of S&T development prospects in Russia**



## 3.2 Methods and tools

The foregoing approach follows the state-of-the-art international practice of dealing with challenges of this sort[18], and takes into account the newest ideas of modern Foresight-researches, which were mentioned earlier (in particular the analysis of grand challenges, weak signals, etc.). The third cycle of the technology Foresight is based on the implementation of methods which reflect its particular characteristics to the highest degree and has proven effective in the practice of Russian and foreign researches[19]. The instruments of the project in question are presented in table 2.

Table 2. Research methods used within the framework of the third cycle of the S&T Foresight.

| Method | Purpose |
|---|---|
| Analysis of global trends and grand challenges | Identification of the drivers and tendencies for S&T development in prioritized fields and key sectors of the economy |
| Bibliometric and patent analysis | Determining the most prospective S&T fields, including the implementation of instruments for the identification of research forefronts |
| Mapping stakeholders | Identification of the centers (“bundles”) of concentration of relevant information regarding prospective fields of science, innovational markets, etc. |
| Quantitative models and scenarios | Forming a macro-economic forecast for the Russian economy |
| Qualitative models | Evaluation of key characteristics of the shape of things to come in the selected fields of S&T development and sectors of the economy |
| Road maps | Establishing the primary markets, products, technologies and administrative solutions in the prioritized fields of S&T development and sectors of the economy |
| Extended interviews, focus-groups, expert | Organization of the work for a wide |

[18] As examples for the implementation of this approach, one can present national scientific-technological Foresights, which were carried out in the last several years in the Check Republic, China, Japan, and a line of issue-related projects - Future of Aviation, Digital Europe 2030 and others (see: http://www.foresight-platform.eu/briefs-resources).

[19] According to the survey of the European Foresight Monitoring Network, when carrying out Foresight-projects on the national level, the average number of methods varies between 4 to 8, at the same time a quite limited circle of methods is usually being used [*Popper,* 2009].

| | |
|---|---|
| panels, questionnaire surveys | circle of experts and gathering relevant information for forming forecasts and scenarios as well as a long term forecast for the fields of fundamental research |
| Seminars and conferences (including international) | Validation of the obtained intermediate and final research results |

One of the main functions of modern Foresight, which allows successful obtaining and implementing its results, is a communicative one[20]: the task of forming a network of experts, as part of transforming Foresight into a truly effective S&T policy instrument is fulfilled in the majority of the developed countries. Usually, such network structures include leading experts – scientists, innovators, marketing specialists; their number can vary from a couple of dozens (when carrying out scenario workshops or brainstorming sessions), to a couple of thousands (in the Delphi surveys). In the British Delphi [Loveridge et al., 1996] for example there were 2960 participating experts, and in the Japanese 9$^{th}$ Delphi [NISTEP, 2010] – 2900.

The insufficient level of fulfillment of the communicational function, according to the evaluation of international specialists who participated in the discussion of the challenges for long term forecasting in Russia, is one of the foremost serious limitations, which the Foresight-research in Russia is dealing with nowadays[21]. The reasons lay not only in what the experts like to often call the "Soviet legacy", which established a misbalance between the demand and supply in the results of researches and development, or in the low level of innovational activity by the companies and lack of innovational culture [OECD, 2011 and others], but also in the mentality of the Russian experts' community which is primarily oriented towards decision making within the framework of narrow influential groups, rather than basing them on a broad communicational platform[22]. Considering all this, the number of fully functioning stable communicational platforms, where an effective discussion of the Foresight-research results could actually be held, is obviously insufficient.

## 3.3 Organization

One of the main tasks of the third cycle of the S&T Foresight, which deals with forming a Russian Foresight environment, is to fill the abovementioned gap. In the course of the realization of this project it will be necessary to provide a significant *development and enhancement of the communicational platforms network*, which is designed to "snatch" the initiative from "the bottom",

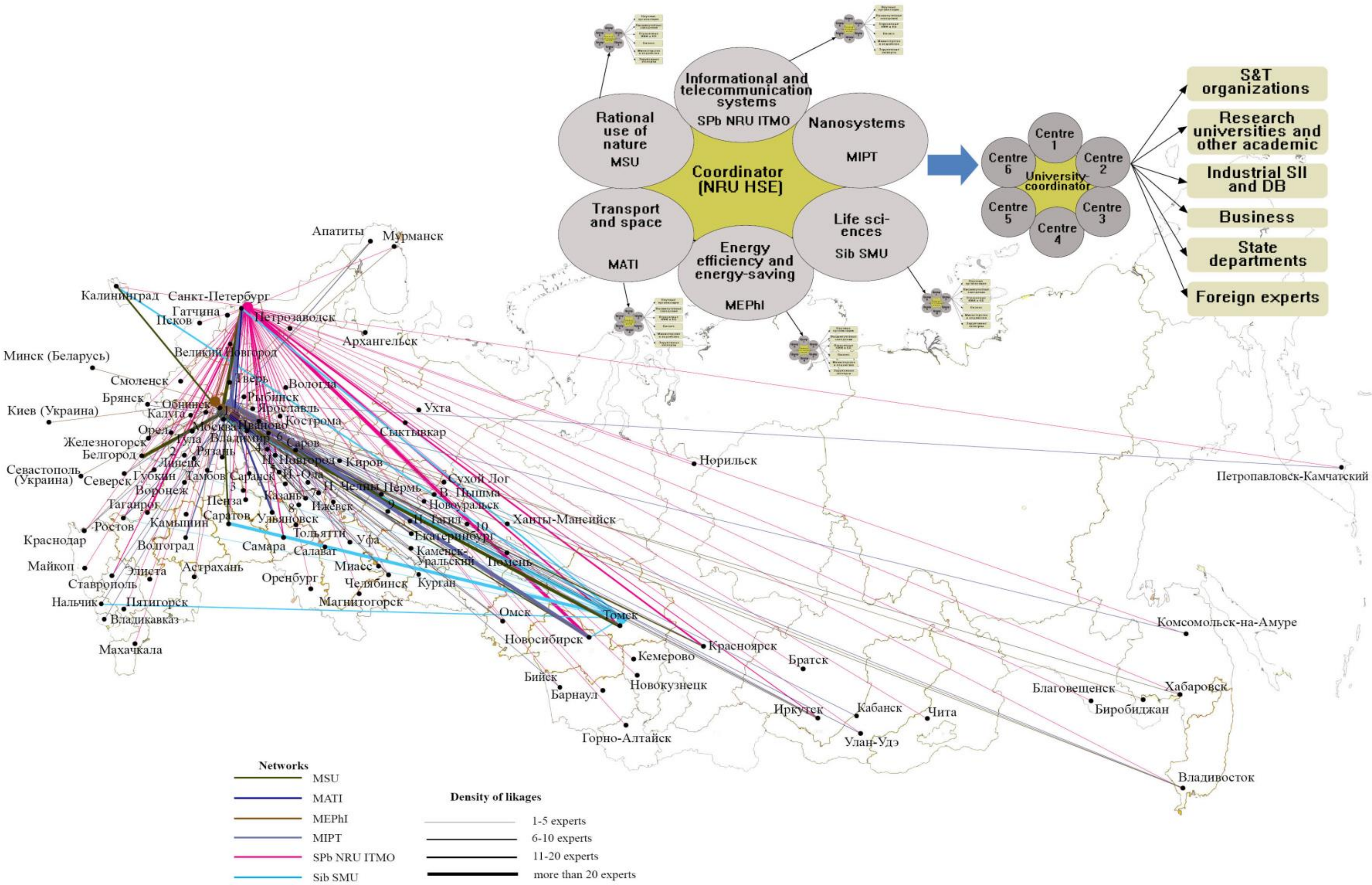
[20] For more details on the key functions of Foresight, see [*UNIDO*, 2005] и www.forlearn.jrc.ec.europa.eu.

[21] This in particular was also discussed by foreign experts during the conference of the International Advisory Board, which took place at the Foresight-center of the NRU HSE in October 2011.

[22] For more information on these and other particularities of the Russian experts' community – see [*Kara-Murza*, 2008].

by creating, on the basis of leading academic institutions, an infrastructure of centers for technology forecasting in six S&T development fields: information and telecommunication systems, nanosystems, life sciences, power industry and energy efficiency, transport and space systems, rational management of natural resources. Such a network, allowing for the active participation of representatives of leading Russian science schools, companies, industrial community, ought to contribute to organizing continuous monitoring and forecasting of the development of the segments of the prioritized fields within their competence spheres, and they need to provide for the necessary PR-support. In the first months of 2012, the network included more than 100 participating organizations, and the total number of experts involved in the project exceeded 1500 people (diagram 5).

**Diagram 5. Organizational scheme of the centers for S&T forecasting and the assignment of their experts by regions**



In addition, for the purpose of evaluating the intermediate and final results of the Foresight for the primary S&T development fields, work groups were formed, which include high profile experts (more than 120 scientists with a worldwide recognition, including active members of the RAS and the industrial science academies), as well as extended work groups, which include scientists and representatives of the government, businesses, expert community, totaling more than 800 people. On top of that, an expert panel was organized to validate the forecast results; the panel involves more than 30 well known foreign specialists in the sphere of long term forecasting and innovation policies, representing leading international Foresight-centers (the University of Manchester, the Institute of prospective technological researches of the United EU research center, OECD, UNIDO and others). This kind of international expertise is prevalent when the effectiveness of results of the national Foresight is evaluated[23].

It is worth mentioning that the problem of analyzing the effectiveness of the completed Foresight-projects, the degree of their impact on the decision-making processes in the sphere of scientific-technological policies and the search for ways to make them more policy-friendly, are at the forefront of the issues concerning the providers and the ordering parties of the Foresight-researches all around the world [Meissner, Sokolova, 2012]. From this point of view, the tasks of the third cycle of the long-term S&T Foresight, concerning the *development of instruments, aimed at supporting decision making based on the Foresight results*, are quite correspondent with the modern rhetoric and agenda. For these purposes three types of work are planned: the first one involves preparation of road maps as an instrument of visualizing the forecast results; the second one is oriented towards forming a unified system of forecasting S&T development activities in, the necessity of which is triggered by the lack of coordination and methodical ambiguity, which make it difficult to implement different indicators, listed in the key documents that determine long term national S&T development. The third group is dedicated to developing recommendations for active implementation of the forecasts' results through policies, particularly when choosing the priorities of S&T development on the regional level.

# 4. Findings - Results of the 3rd cycle of S&T Foresight 2030

## 4.1 Overview of results' basis

The study was based on more than 200 sources including Russian and international S&T foresight studies, analytical reviews, and other publications devoted to specific research areas. The summary recommendations presented below have been prepared with the help of a large number of

[23] One of the most interesting examples of evaluating national Foresight is presented in the work [*Popper et al*., 2010].

experts involved in selection and identification of priority areas for applied research, and their subsequent verification in a series of events, including the following:

- Expert panels held in 2011-2012, which comprised more than 150 leading Russian and international scientists;
- International workshops and conferences at major global research centres and universities, including American Association for the Advancement of Science (USA), Austrian Institute of Technology, Beijing Institute of Technology, Grenoble School of Management;
- Meetings with the International Foresight Advisory Board at the Institute for Statistical Studies and Economics of Knowledge of the National Research University Higher School of Economics, which comprises leading international Foresight experts and representatives of international organisations including OECD, UNIDO, European Commission and prominent Foresight centres (the EU Institute for Prospective Technological Studies: Fraunhofer Institute for Systems and Innovation Research; Manchester University; Ottawa University, Telfer School of Management, et al.)

The results obtained from the study have been used in the course of development of the Russian National program “Development of Science and Technology”, which was approved by the Russian Government regulation #2433-r of 20 December, 2012.

The report highlights promising innovative markets, products and services, key research topics and relevant priorities for applied research in each of the areas above with the assessment of Russia’s current level of research competence with a benchmark to the players across the globe.

Thus, the results of the long-term foresight identify future-oriented S&T research and results to be achieved, which may serve as a bridgehead to create Russia’s “entry points” to international markets with the integration of the country into international alliances, and its positioning as a global technological development centre. The study also reveals a number of “white spots” of critical areas for the creation of a prosperous future economy, where Russian S&T is significantly lagging behind the world leaders, and often without any relevant R&D potential. The long-term priorities for applied R&D presented in this report are considered to be of a practical interest to government agencies, companies, R&D organizations, universities, technology platforms, and territorial innovation clusters.

Below certain most significant trends, challenges, threats and directions of development of research are highlighted, regarding 7 traditional directions[24] of science and technology development[25].

## 4.2 Information and Communication Technologies

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[24] According to List of Russian Federation critique technologies, 2011. Online: http://news.kremlin.ru/media/events/files/41d38565372e1dc1d506.pdf

[25] For details, see: Russian Long-Term S&T Foresight 2030. Moscow: Higher School of Economics, 2013.

Information and Communication Technologies (ICT) are among the key drivers of the shift towards a knowledge-based economy. Their development contributes to increasing the quality of life, efficiency of private businesses and public administration, emergence of new forms of education systems, better communication and interaction of individuals with access to a wide variety of information in almost all aspects of life.

Despite the fact that the ICT domain demonstrates a quite dynamic life cycle of relevant technologies, products and services, the role of accumulated pool of S&T results in this area remains very important. Based on the expert panels' conclusions, eight applied research areas were identified with particular importance to Russia.

The results which can be obtained to 2030 include prototype systems based on new computational principles; prototype multilanguage programming systems for knowledge extraction and formalisation; data processing technologies to solve the Big Data problem; Next-Generation Business Intelligence with new analytical tools, including personal analytical systems, tools for real-time data processing, mobile analysis, etc.

The highest market growth rates for the aforementioned S&T products are expected to be in such areas as health, power engineering, mechanical engineering, transport, and in personal consumption of ICT products and services. In the medium term (to 2020), the experts expect introduction of electronic health passports; emergence of distributed networks of telemedicine centres; development of quality control and safety system for drugs and medical services. By 2025, medical micro-devices are expected to emerge, implanted into the body to support its vital functions; technologies for exchanging standardised data between transport vehicles; universal global positioning and identification techniques within the framework of the "Internet of Things" concept; promising platforms for collecting, summarising and presenting content and knowledge. The experts noted possible integration of inbuilt digital devices into mechanical engineering products, and development of programming technologies for inbuilt systems.

Evolution of cloud computing and the development of new architectures and computational principles lead to transformation of software and may bring radical changes in business strategies of companies operating in all sectors of the economy. A colossal growth of data volume available for analysis provides a foundation for a radical increase of efficiency of managerial decisions, including in the analytical business applications segment (Business Intelligence).

However, according to experts, Russian developers' skill set does not cover all the areas of applied research required to obtain prominent positions in the prospective markets – not by a long shot. One of the most advanced areas includes "New data transfer, networking, and content distribution technologies". In areas, such as "Computer-aided element base design technologies", "New data transfer technologies", "Digital reality technologies and systems, prospective human-ICT interfaces", the level of Russian research did not receive high marks.

## 4.3 Medicine and health

Increasing the quality of life and prolonging life expectancy is a major priority of the government policy as an indicator of the country's strategic development and national security progress[26]. Accomplishing these objectives largely depends on the level of future-oriented R&D and its results, which have become much more important in the recent years. The experts identified seven topics for applied research as the most promising ones for Russia.

The key trends identified in this area include growth of oncological, cardiovascular and infectious diseases; ageing of the population; ubiquitous spread of metabolic diseases and brain pathologies. In turn, these challenges create new international markets, and their dynamics will be closely linked to the demand for diagnostics and treatment techniques based on personalised medicine principles, reliable non-invasive express monitoring technologies for home application, technologies for remote access to preventive, safe and highly effective medical services.

There is already a strong demand for an increased quality of life, especially in terms of restoration of totaly or partially lost functionality of the body or organs. Research and development in bio-information, post-genomic and proteomic technologies provide an opportunity to personalise therapeutic effects. For instance, drugs would be prescribed on the basis of analysis of the patient's individual features. According to the expert evaluations, at least half of new drugs, which are expected to appear on the international markets by 2015 will have pharma cogenetic properties. Regenerative medicine technology is a major area of modern R&D, which is expected to address brain, locomotorium, oncological and many other diseases. The leading countries of the world have already achieved promising results in human organs regeneration, while Russia has practically made no progress in this area.

According to the experts, by 2015 Russia may expect to achieve significant scientific and practical results in the following fields: "Biocompatible biopolymeric materials"; "Self-sterilising coatings for medical applications"; "Testing systems based on genomic and postgenomic technologies, for diagnosing cancer, system, infectious and hereditary diseases"; "Biosensors and biochips for clinical diagnostics, based on new types of biological devices"; "Techniques for quick identification of toxic substances and pathogens".

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[26] See e.g. [the RF President's address to the Federal Assembly, 2012].

Success achieved in innovative pharmaceutics – biotechnologies, chemical synthesis technologies, targeted therapeutic effects, production of advanced effective vaccines – would allow Russian companies to enter promising international markets, and it would let the government raise the citizens' quality of life.

In a number of areas, such as "Gradient ceramics-based biodegradable materials" and "Medical textile with unique therapeutic properties", the potential of Russian developments is already considered significant. Further advancement of future-oriented research and securing advantages would require development of existing and establishing new translation medicine centres, for the development of pre-clinical technologies.

## 4.4 Biotechnology

Dynamic development of biotechnology can be explained not just by the advances achieved in biochemistry, bio-organic chemistry and molecular biology, but also by the crisis of traditional technologies (especially when considering the new trends, particularly environment- and energy-related); the need to ensure food supply, raw materials, and medical security; sustain the supply of resources; increase people's lifespan; and support healthy national gene pool.

Future-oriented research plays a major role in developing adequate responses to these challenges. Based on the results obtained from expert panels, seven topics for applied research were identified as the most promising for Russia within the priority research area in question. Their development would help to achieve economic growth, enter high-technology markets, and accomplish numerous national first-order objectives.

Development of various kinds of biofuel will contribute to the diversification of the fuel-and-energy balance and reduction of the greenhouse gas emissions. Cellular, genomic and post-genomic technologies would enable making biomaterials from renewable raw materials, replacing traditional chemical production and developing innovative products with unique properties. They would also help to bring back rare and endangered flora and fauna species, and to preserve oceanic resources. Improvement of technologies for bio-organic waste processing will help solve the problem of waste disposal, and reduce environmental pollution. Introduction of new highly productive bio-objects, and application of efficient operating practices will allow to significantly intensify production processes. Development of technologies for producing new varieties of agricultural plants and new breeds of animals with improved properties would  enable producing sufficient quantities of high-quality food.

At the same time achieving the above-mentioned effects and securing a meaningful niche on promising emerging markets require a radical improvement of Russian producers' competency levels, which currently are quite uneven. Among the most advanced applied research areas the experts identified “High-performance techniques for genome, transcriptome, proteome, and metabolome analysis”; “Systematic and structural biology”; “Microorganism strains and microbe consortia for creating symbiotic plant-microbial communities”. On the other hand, in a number of other areas, such as “Biotechnological processes for making biomaterials, fine and mainline organic synthesis products from renewable raw materials”, “Techniques for building genetic databases of plant varieties and seed certification”, “Environmentally safe biocides”, the level of Russian research conducted in recent years remains insufficient.

## 4.5 New materials and nanotechnologies

Changes in the present image of the economy and society are to a large extent linked to large-scale application of new materials and nanotechnologies in production processes and the service sectors. According to optimistic assessments, the first noticeable effects, primarily in nanoelectronics, photonics, nanobiotechnology, medical products and equipment, neuroelectronic interfaces, and nanoelectromechanical systems, can be expected as early as within next five years. The largest breakthroughs of the next decade may include molecular production of macroscopic objects (“desktop nanofactories”), and emergence of atomic design. Convergence of nano-, info-, bio-, and cognitive technologies potentially may lead to extending the active stage of human life.

Possibly, the above-mentioned areas would largely determine the level of technologies of the future; however, due to specific features of the field under consideration here, it does not seem possible to predict exactly which segments have the best chances of achieving breakthroughs. Large expectations are first of all associated with the development of hybrid structures combining organic and non-organic fragments, live tissues and synthetic components capable of giving them new properties; with development of nanocomposites, which would allow to make materials of unique strength, elasticity and conductivity – particularly important for achieving progress in alternative power engineering; with mathematical modeling of nanomaterials’ properties, which is expected to significantly accelerate creation of new systems with useful properties.

Nanomaterials will also play a major role in dealing with economic problems, since they are at the core of advanced sensing and water treatment technologies, separation processes, and many “green chemistry” areas. They serve as a basis for the development of numerous drugs, targeted delivery systems for them, and express diagnostics technologies for live organisms.

The experts were in agreement on the majority of application areas - future markets for nanotechnologies and new materials. For example, the application of nanotechnologies is expected to become more active in lighting equipment, sports, textile industry as early as by 2015; and extended application of nanotechnologies in automobile and aerospace industries, shipbuilding, food industry, and construction is foreseen by 2020-2030. In the medium term, the emergence of markets is expected, which would combine large volumes and high growth rates, specifically: nanotechnological applications in automobile production, mining and processing equipment, pharmaceutical and medical equipment, power engineering.

Russia's chances for participating in these major changes, or even taking a leading position in certain areas, are largely determined by the level of future-oriented research within six most promising fields identified.

Unlike most of the other priority areas for applied research discussed in this report, the level of Russian R&D in nanotechnology and new materials was evaluated by the experts as quite high, particularly in such fields as "Nano-size catalysts for deep processing of raw materials" and "Nano-structured membrane materials". However, there is also a number of "white spots", where the level of Russian R&D was judged to be low. These, for example, include "Construction materials for power engineering".

## 4.6 Rational use of nature

In the era of globalization and rapid development of science and technology, natural environment becomes increasingly vulnerable. Continuing with the established inertial environment management scenario in the future is unacceptable and involves significant risks in terms of possible loss of life and limitation of economic growth. Most of the global challenges the humankind will face in the near future are connected with the environment and its inefficient management. These include, first of all, depletion of several critical resources; climate change; growing anthropogenic pressure and pollution of natural environments; loss of biodiversity, etc. Future-oriented research certainly plays a major role in developing systemic and integrated responses to these challenges. However, if the international community has already realised the importance of moving on to the environmentally friendly development ("green growth"), in Russia these topics are traditionally treated on the basis of the "leftover principle".

Based on the results of the expert panels' discussions, this report presents four thematic fields for applied research under the "Rational use of nature" priority area, as the most promising for Russia. Results which could be achieved before 2030 include the development of systems for monitoring the state of environment, assessing and forecasting natural and anthropogenic emergencies; exploration and integrated development of mineral resources; highly efficient and safe techniques for marine prospecting and mining of hydrocarbons under extreme natural and climatic conditions. Their development and implementation would lead to more efficient utilisation of the country's mineral resources and their reproduction; decreasing the level of environment pollution; and minimising damage caused by natural and anthropogenic emergencies.

Gradual transformation of environmental technologies from a cost item into a revenue-generating factor which contributes to increasing the investment flow and entering new markets has become a significant trend in recent years. According to the expert estimates, in the medium term (by 2020), the following application areas for these technologies will have the highest growth rates: environmentally clean materials and products; software and geoinformation systems; equipment and materials for increasing efficiency of mining and processing of minerals; systems for early detection and forecasting natural and anthropogenic emergencies. In the long term (2020-2030), significant growth is expected on water treatment and recycling markets; environmentally safe waste disposal; secondary raw materials and finished products made by recycling waste and drainage, and related equipment.

For Russia, the need for future-oriented research in the rational use of nature is due not just to the opportunities to secure significant shares of the abovementioned promising markets, but also because of the threat to lose its current positions in the traditional segments – as a consequence of continuous toughening of international environment-related standards for product quality and for the technologies used for their production. Solving this multifaceted problem requires advanced qualifications for Russian researchers and developers in all of the applied research areas mentioned above.

## 4.7 Transportation and space systems

In the near future, transportation systems will become a basis for development of accessible, inexpensive, safe, fast and predictable transport links, both on regional and international levels. Improvement of transport communications will bring about the "space compression" effect – i.e. distances between locations would seem much shorter to consumers of transport services. Achieving that kind of socio-economic effect involves various applied studies across the whole transportation complex, including aviation and space.

First of all, efficiency of transport planning must be significantly increased – by creating transport-economic balance and applying advanced modelling techniques. Increasing accessibility and quality of services, effective speed and stability of transport in the current situation of heavy traffic – is a serious challenge, and the only way to meet it is by developing new-generation transport technologies. Another challenge related to organisation of high-speed transportation is the need to increase people's mobility, which was noted in the RF President's address to the Federal Assembly of 12 December, 2012 [the RF President's address to the Federal Assembly, 2012].

An efficient modern transportation complex can become a "locomotive" of the Russian economy, and promote the country's innovation-based development; however, to create it significant financial resources are required, which cannot be obtained exclusively from the federal budget. Therefore the key economic challenge for the transport sector is increasing its investment attractiveness – which can be achieved by reducing costs, increasing efficiency of construction and maintenance of infrastructure, and increasing productivity.

At the same time several international high-tech markets still look quite attractive for Russian companies. According to the expert assessments, the highest growth rates in the medium term can be expected for smart transportation systems and new management systems, as well as environmentally safe and energy-efficient transport vehicles. Particular attention should be paid to markets whose growth rates can increase after 2020. These first of all include multimodal passenger and freight transportation and logistics systems; new materials and technologies for transport construction; prospective transport vehicles and systems; and space services.

Among the most competitive areas of Russian R&D the experts noted "Development of research models to study transport situation in the Arctic and subarctic areas", "Development of air- and spacecraft to launch suborbital small-size space satellites", and several other topics related to new-generation carrier rockets and spacecrafts, innovative transportation vehicles and systems for marine and air transport. Still, this is by no means an exhaustive list of priority S&T development areas matching the forecasted dynamics of global markets.

## 4.8 Energy efficiency and energy saving

The state of the energy industry largely determines the overall competitiveness of the economy, the society's development level and the quality of the environment. In Russia, the need to ensure long-term sustainable and efficient development of the energy industry is defined by the country's leading export positions, and the industry's role in generating government budget revenues. The industry is highly inertial, has a long investment cycle; development of new technologies involves high costs and a lot of time, and requires interdisciplinary research. Also, practically in every case there are several possible S&T development areas to pursue, and a wrong or non-optimal choice can result in major losses and increased lagging behind the leading countries of the world. Accordingly, identifying long-term global energy trends and conducting relevant future-oriented research become particularly important.

Regarding fossil fuel production, among the most important research and development areas there are robotic installations for submarine and subterranean hydrocarbon production, remotely controlled and with prolonged automated operation periods; development of technologies for efficient hydrocarbon production at nonconventional sites (including gas hydrates, oil sands, extra-heavy crude oil, shale gas, coal strata gas) and under anomalous conditions (dense formations, abnormally high pressure, ultra-deep horizons, large depths, low volume density of resources, etc.). Technologies for deep processing of off-grade resources of natural gas and low-quality coal, used to produce competitive motor fuels and chemical products, are also being actively developed.

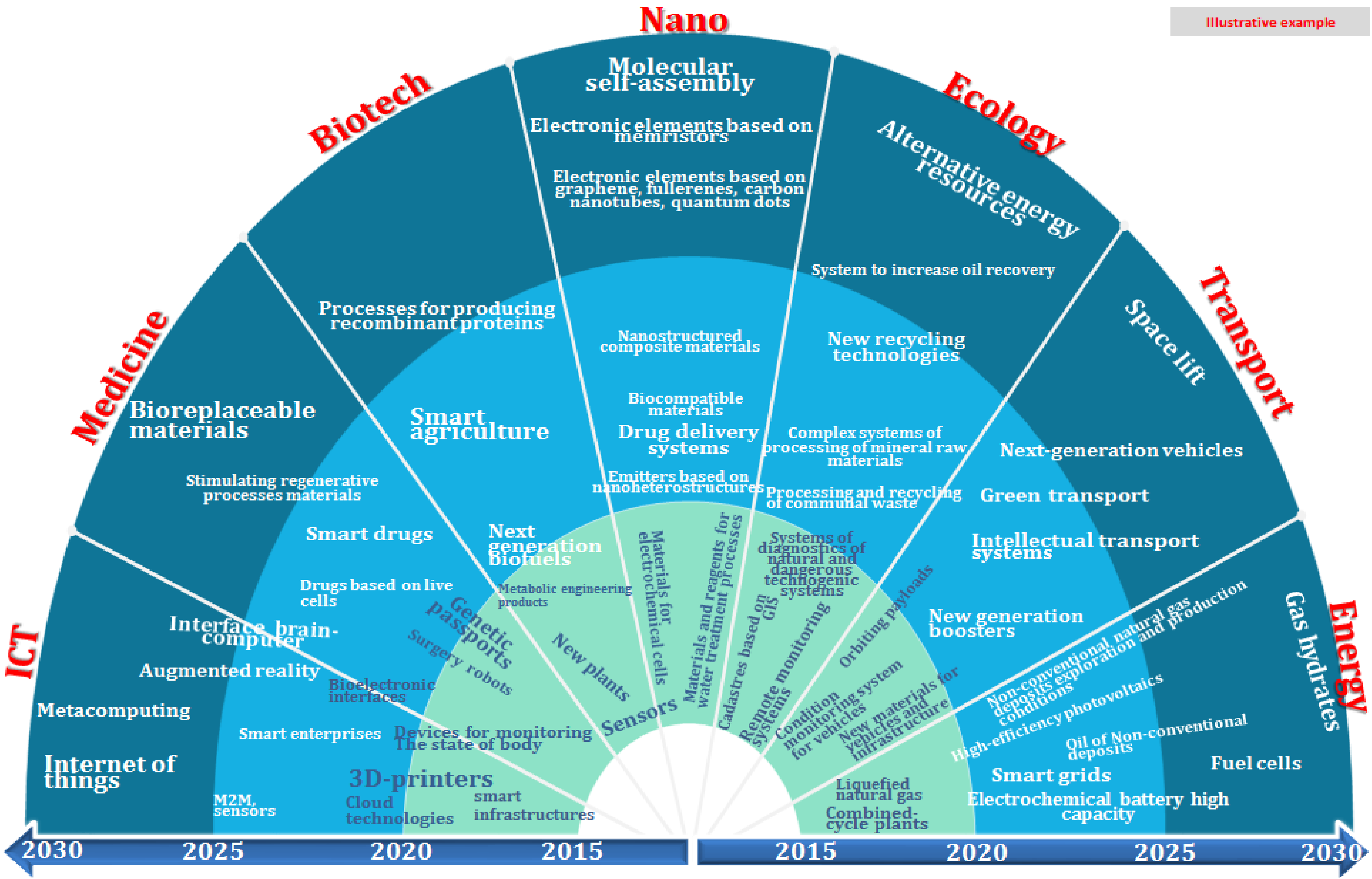
A clear trend in heat and power engineering is the development of materials and technologies for making highly flexible high-power gas-turbine installations with maximum efficiency factor and minimum pollutant emissions, which in the future are going to become the foundation of major energy industry. Also under way is active research of fast reactors' safety and safe closed nuclear cycle – an important element of centralised electric energy supply. Future development of low-power energy installations is connected with the production of low-temperature fuel cells with extremely high efficiency factor and long service life, without specific requirements to fuel quality, and low production and maintenance costs.

Regarding sustainable energy production, the range of research topics being pursued is quite wide: designing inexpensive photoelectric converters with very high efficiency factor and long service life, utilising the full solar radiation spectrum; developing technologies for high-capacity marine wind-power engineering, to ensure reliable operation of deep-water far-from-shore installations; developing high-performance hydrogen production technologies based on photochemical and electrolytic water decomposition. As for distributed energy generation from sustainable sources, high-capacity and high-power low cost energy storage technologies are becoming of critical importance.

Bioenergy plays a serious role as it is becoming a new segment of the industry, *a priori* environment- and climate-friendly. Development of energy saving technologies and equipment remains among the major trends of power engineering. R&D aimed at creating smart local-level energy systems with real-time automated management of energy consumption based on integration of electric grids and information networks are expected to speed up solving of the energy supply problem. The above-mentioned applied research areas would contribute to radical transformation of traditional markets, and create conditions for the emergence of new ones. Among the promising and attractive to the Russian market segments, the experts noted the following: electricity, heat and cold storage; nonconventional oil markets; equipment for sustainable energy production; fuel cells; bioenergy technologies. Expert evaluation results of Russian research in the "Energy efficiency and energy saving" area vary quite significantly from "white spots" in such fields as "Gasification of new-generation solid fuels” and “Remote control of power-generation equipment” to significant advances comparable to the top global level (in particular concerning fast neutron nuclear reactors’ safety, mining of certain nonconventional resources and hydrocarbons).

Detection of technology and product «jokers» was among the most important targets of this project. Onwards «Radar» of mass diffusion of radical products and technologies in the range key S&T research directions (presented above) for Russian Federation is exemplified on the diagram 6.

**Diagram 6. «Radar» of mass distribution of radical products and technologies in key S&T research directions for Russian Federation**

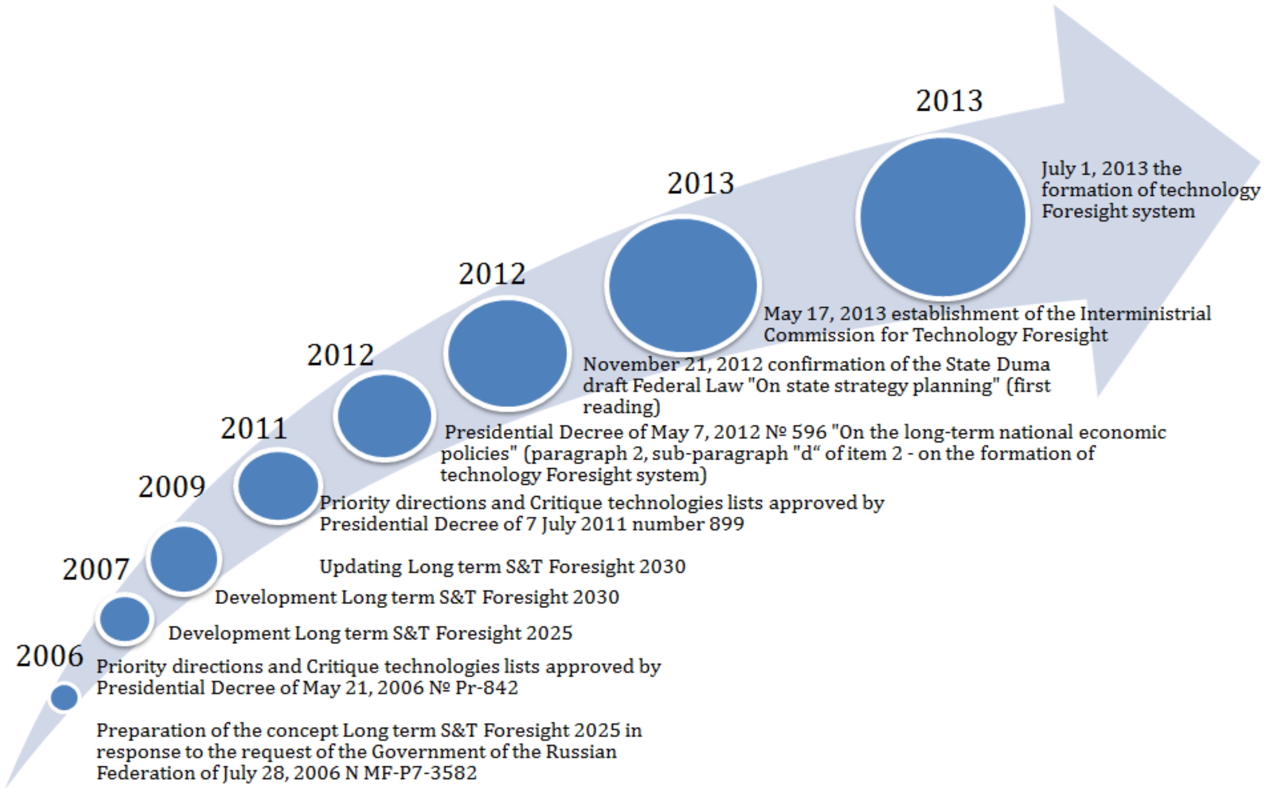


## 5. Creation of a national foresight system and using Russian S&T Foresight 2030 results in the STI policy framework

The beneficiaries of the Foresight results can be the interested state departments, who are responsible for forming S&T policies; governmental cooperation in the development of S&T strategy with a long run planning horizon; large Russian high-tech companies; development institutions which are oriented towards supporting innovations; regional authorities – for working out regional strategies and territorial schemes for research and development; the scientific community – for determining the calls for R&D fields, and promoting technologies through created communication platforms; and the business community – for forming strategies for development of enterprises and investors' projects which deal with technological modernization.

Currently in Russia the STI policy framework conditions changed significantly : July 1, 2013 in accordance with the decree of the President a national technology Foresight system was formed, focused on ensuring the future needs of the manufacturing sector national economy, including the development of key industrial technologies (hereinafter – Foresight system). In order to ensure the organizational and coordination support a commission on technology Foresight of the Presidium of the Presidential Council of the Russian Federation on economic modernization and innovative development of Russia was established (hereinafter - IC). Diagram 7 shows the dynamics of the background development of technology Foresight in Russia.

**Diagram 7. The dynamics of the development of the S&T Foresight in Russia**

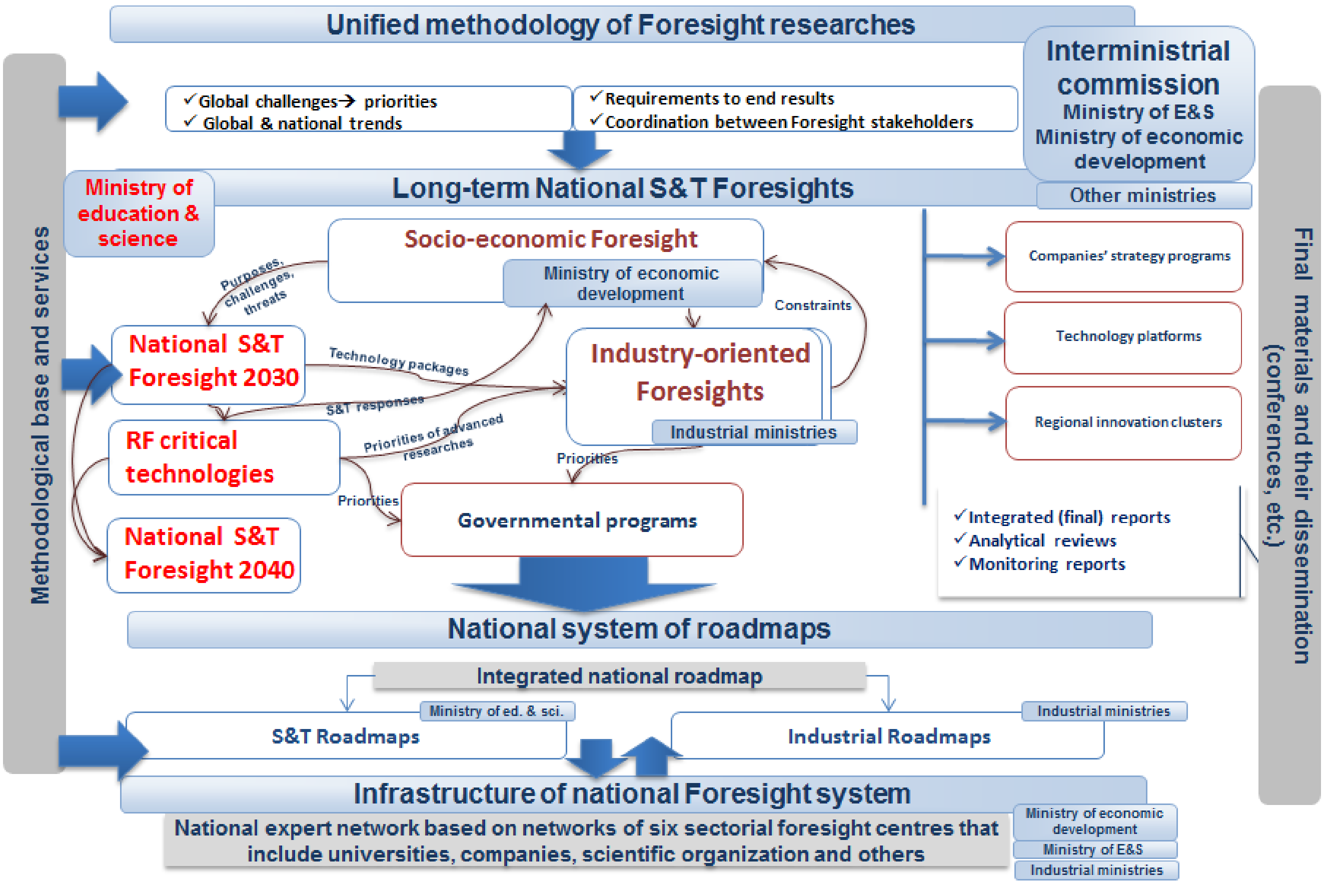


Objectives of the Foresight system can be divided into two main groups:

1. **functions to achieve the final results:**
    a. to develop a long-term national S&T Foresight;
    b. to form and update national lists of priority areas of S&T development and critical technologies;
    c. to develop long-term industrial S&T Foresights;
    d. to create and update industrial critical technologies;
    e. to monitor annually of development of S&T sphere;
    f. to develop roadmaps of sectors and areas of S&T development;
    g. to prepare proposals for the use of the results of the Foresight system in strategic documents of the State strategy planning system.
2. **functions to provide the effectiveness of system work:**
    a. to coordinate and provide methodological support for the federal executive departments and agencies and other stakeholders in the Foresight system;
    b. to develop and support a national expert database;
    c. to develop communication platforms for discussion results;
    d. to improve the methodology and develop a common framework of project standards within Foresight system;
    e. to form a united public database of Foresight materials.

To provide methodological and organizational support for IC a particular study has been conducted, the results of which have defined the fundamental architecture of the Foresight system (see diagram 8).

**Diagram 8. Principal architecture of national foresight system of Russian Federation**




Also currently the system of state strategy planning of socio-economic development of Russia (according to the same decree of the President) is being formed. This process is supported by the draft federal law "On the state strategy planning", which provides coordination of strategic management and fiscal policy measures.

According to the reorganization of the institutional conditions for the development of STI policy Russian Long-term S&T Foresight for the period up to 2030 is one of the most important documents in the state strategy planning system aimed at methodological, information and expert analytical support for decision-making on the national level. Its main task is to set priorities of S&T development of Russia the various levels of national innovation system.

The 3rd cycle of S&T Foresight 2030 highlights a wide range of S&T areas of development, most promising in terms of their implementation in Russia. Foresight results are varied in their nature - not only defining R&D areas, but also promising markets and product groups, coupling with which one can use their results.

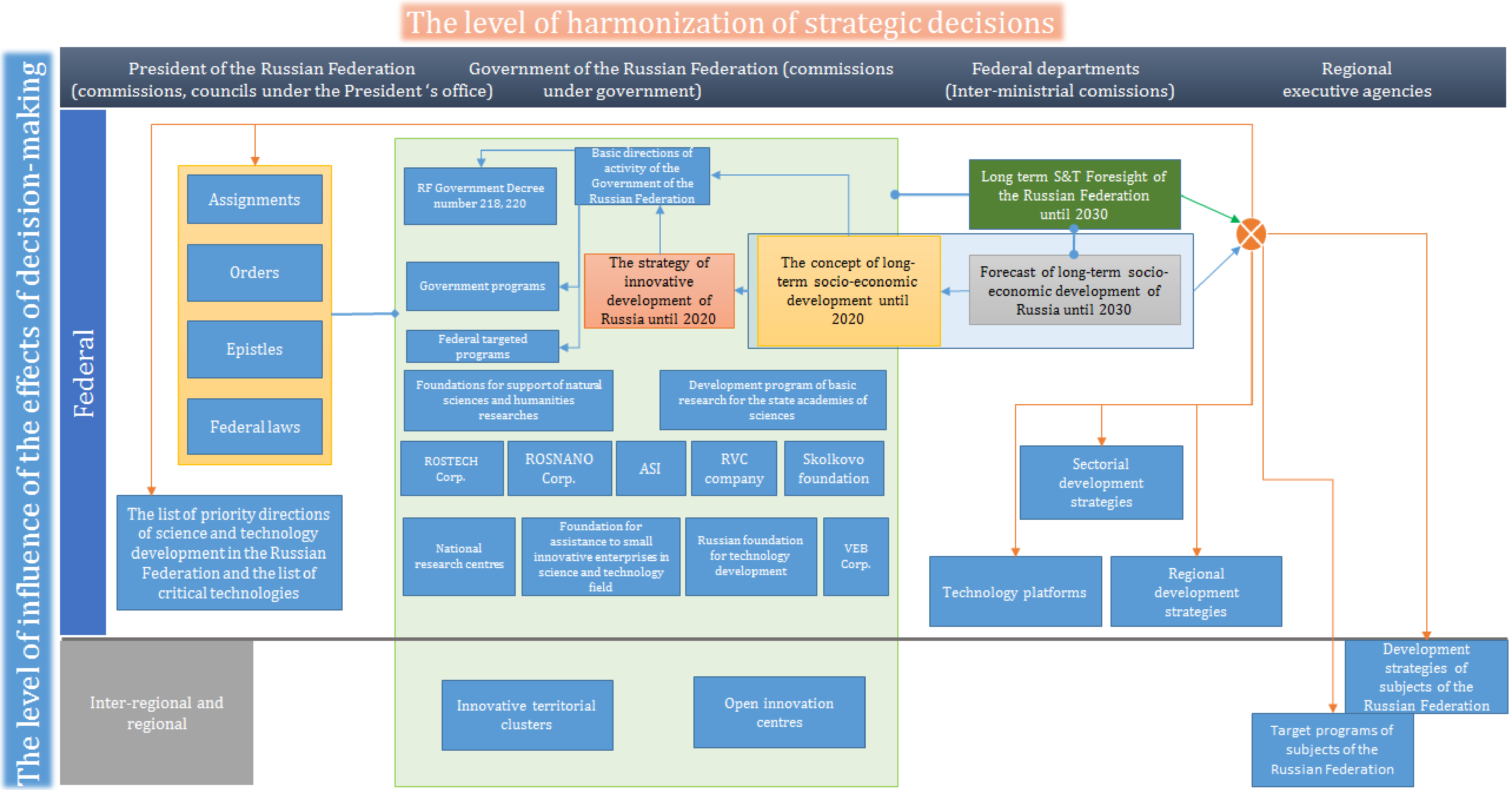
The national system of technology Foresight provides a gradual alignment of mechanisms for the usage of the Foresight results, including:

Step 1: informing interested stakeholders about the results of the Foresight, joint designing of mechanisms of their usage  involving federal executive departments and other organizations;

Step 2: formatting mechanisms for the usage of the Foresight results in the development, implementation and adjustment of public programs of the Russian Federation, including the federal target program with S&T orientation;

Step 3: creating mechanisms for the usage of the Foresight results in the development, implementation and adjustment of strategy planning documents of the state socio-economic development.

**Diagram 9 shows the strategy instruments of S&T and innovation policy in Russian, which may use the long-term Foresight results**



In conducting a comprehensive analysis of the stakeholders in the Foresight system and their demands for prognosis information were identified 5 major groups of materials and 9 types of interested actors. Results of this study are aggregated in the form of a matrix of integrating the results of the long-term Foresight in strategic decision-making processes at the level of various players in the national innovation system (see table 9).

An equally important element of the long-term S&T Foresight is a series of non-formalized results, such as the creation of a network of sectoral Foresight centers and of related infrastructure at leading universities, the development of communication platforms and the establishment of stable relationships in the expert and professional communities. This is not represented in the matrix of integration (table 9), as the beneficiaries here are all the declared stakeholder groups, and a strategic platform was created for them with horizontal channels for exchanging ideas, initiatives and for coordinating expert opinions.

## Table 9. Integration matrix S&T Foresight results into main stakeholders' strategy decisions

| Main groups of Foresight results (columns) \| Stakeholders of technology Foresight system (rows) | Global challenges and trends, assessment of their impact on the formation of national challenges and the "windows of opportunity", and periods and effects of their maximum influence | Perspective markets and their segments, factors contributing to the formation of new markets | Prospective product groups and related technologies; assessment of the time scales of their appearance and commercialization | The key areas of applied backlog studies and assessment of the level of Russian developments in the thematic areas, including the most promising R&D areas | The most promising areas of integration into global value chains and proposals for the formation of international alliances |
|---|---|---|---|---|---|
| **Federal statedepartments and agencies** | • Analysis and forecast of global and national developmental trends for tools of targeted program planning and development of strategies at various NIS levels<br>• Formation of multiple alternative scenarios of global and national development<br>• Evaluation of the elements of the risk system, which takes into account future trends, challenges and threats<br>• Formation of the risk portfolio of different strategies and the development of measures to manage them | • Justification and development of the objective value of the state S&T development programme indicators<br>• Analysis and forecast for the promising markets for the development and updating of strategies (national and sectorial) and state programs<br>• Creating and updating the system of priorities to support R&D in government policies and programs on the national and sectoral levels<br>• The development of the internal consentient view of the contours of the future technological profile of the Russian economy and the situation in the field of S&T interests of the various actors of the governmental executive departments<br>• Evaluation and monitoring of development programs for technology platforms, innovative regional clusters, large companies, universities and leading research organizations etc.<br>• Assessment of barriers to the development of innovation systems and resource constraints of the national economy<br>• Evaluation of necessary competence profiles in the type of skills needed and time of their occurrence, working up appropriate measures to support their development<br>• Formation of the federal budget | | | • Evaluation of applications to support projects involving foreign centers of competences and leading scientists |
| **Regional authorities** | • Coordination of the federal and regional assessment of global, national and regional trends, challenges, threats, "windows of opportunity" and their effects<br>• Analysis and forecast of the global and national development to design regional programs and strategies | • Forecast of growth of promising markets for the development and correction of regional strategies and targeted programs | • Creating and updating a priority system to support research and development in the regional target programs and other strategic documents<br>• Formation of regional budgets | | • Evaluation of applications to support projects in collaboration with leading foreign centers of competence and leading scientists |
| **State institutes of national innovation system development** | • Analysis, monitoring and forecast of the global and national context for strategic decision-making on supporting infrastructure development and players in the national innovation system | • Forecast of prospective markets development for working up strategic documents and quick decision-making<br>• Preparation of specifications of market positions of key players in the national innovation system | • Creation of a system of technology and product priorities for the development of strategic actions and decision-making concerning support for infrastructure development and the national innovation | • Creating a system of scientific priorities for working up strategic documents and quick decision-making<br>• Evaluation of necessary competence profiles in the type of skills needed and time of their occurrence, the development of | • The selection of strategic partners to develop programs to support international collaboration and cooperation between leading S&T organizations |

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| | | | system participants’ | appropriate measures to support their development | |
| **Technology platforms** | • Creation of a "future vision" of industries and sectors of the Russian economy, which include technology platforms for the medium and long term periods<br>• Identifying opportunities and limitations on use of the previously created results of intellectual activity | • Analysis of the current and future market trends and technologies in the field of platform’s activities<br>• The development of forecast for the product markets, which are improved within the platforms’ activities<br>• Characterizing the market position of the key enterprises affiliated to the platform, assessing their presence in the most promising market segments | • Formation of medium-and long-term priorities in cooperation between the platform participants in the sphere of technology and product development<br>• Selection of the most promising technical and technological solutions<br>• Evaluation of necessary competence profiles in the type of skills needed and time of their occurrence, working up appropriate measures to support their development | • Formation of medium-and long-term priorities in cooperation between the platform participants in R&D<br>• Evaluation of necessary competence profiles in the type of skills needed and time of their occurrence<br>• Setting priorities and actions for the development of research and innovation infrastructure for the technology platform participants | • Analysis of the competitive environment in the sphere of development and implementation of innovation<br>• Identifying opportunities and limitations on use of the previously created results of intellectual activity in the aspect of the formation of alliances and co-operative development<br>• Formation of plans and actions for the development of international S&T cooperation, searching for strategic partners |
| **Innovative territorial clusters** | • Creation of a "future vision" of industries and sectors of the Russian economy, which include innovation clusters, in the medium and long term range<br>• Assessing opportunities for accelerated development of the cluster<br>Assessing readiness of the cluster to use available opportunities<br>• Identifying the factors affecting the development of the cluster, the risk profiles<br>• Development of the basic mechanisms of compensation of threats and risks | • Analysis of the main products of the cluster, their markets and customers (assessment of the current state of these markets, the characteristics of the market positions of the key participants in the cluster)<br>• Describing key competitive advantages of cluster members, their core competencies and competitive factors in the Russian and foreign markets and evaluating its current level<br>• Identification of markets and segments with the greatest capacity to distribute products of the cluster, including the long-term range<br>• Assessing the current state of market segments (volumes, growth dynamics, etc.) | • Formation of the priority system of the key activities and projects in the field of research and development, which are expected to be realized by cluster members in cooperation with each other in order to improve the technological level, production efficiency and product quality<br>• Setting priorities and actions for the development of research and innovation infrastructure, located in the cluster area<br>• Setting priorities and actions for the development of international S&T cooperation<br>• Assessment of the main production cluster development to produce new products<br>• Development of key measures to promote commercialization of R&D results<br>• Evaluation of necessary competence profiles in the type of skills needed and time of their occurrence, working up appropriate measures to support their development<br>• | | • Organization of guidelines and measures for the development of international S&T cooperation<br>• Formation of an action plan for the development of industrial cooperation with foreign partners, including in particular: the creation of joint ventures<br>• Organizing the supply of materials and components; outsourcing in manufacturing, searching for potential suppliers and partners |

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| | | • Characterizing the diversity of product types<br>• Describing the key characteristics of the market position of enterprises and organizations in clusters, the degree of performance in the most promising markets and segments by the enterprises and organizations of the cluster | | |
| **Large companies that perform innovative development programs** | • Analysis of challenges, threats, problems and "windows of opportunity" to work up the strategic priorities of the innovation development program<br>• Assessment of company's readiness for use of existing opportunities<br>•<br>Identification of factors affecting the development of the company in a negative way, risk profiling<br>• Development of the main mechanisms for compensating threats and risks | • Identification of markets and segments with the greatest capacity to distribute products of the cluster, also in the long run<br>• Planning and organizing the introduction of technological and organizational innovations<br>• Analyzing and forecasting prospects for the development of relevant markets | • Identification of markets and segments with the greatest capacity to distribute products of the cluster, also in the long run<br>• Planning and organizing the introduction of technological and organizational innovations<br>• Analysis and forecasting prospects for the development of relevant markets<br>• Selection, development and monitoring of indicators of the S&T level of the company<br>• Selection of key technologies, products and product groups and the development of plans of their implementation<br>• Selection and justification of S&T priorities in the activities of technology platforms and innovative regional clusters, measures to promote co-operation with universities and small and medium-sized enterprises, as well as the development of innovative infrastructure measures<br>• Development and selection of key performance indicators (KPI) | • Choosing of foreign companies to analyze the world's best practices and opportunities for adaptation<br>• Choosing of Russian and foreign partners for the development of S&T cooperation |
| **Institutions of higher education** | • Analysis of the challenges, threats, problems and "windows of opportunity" of global and national educational systems for setting the strategic priorities in the university development programs for<br>• Development strategies for compensating the threats and risks, using "windows of opportunity" | • Working up optimal trajectories for the development of individual units of the university to the forefront in the global academic and scientific community<br>• Creating a system of R&D priorities with a clear focus on the needs of large and medium-sized businesses in Russia and abroad<br>• Assessment of the real position in the global coordinate system of universities and research organizations worldwide<br>• Defining strategies of the world's leading centers of competence, the development of profiles of leading scientists and experts in the claimed subject areas of the university S&T development programs<br>• Evaluation of necessary competence profiles in the type of skills needed and time of their occurrence, working up appropriate measures to support their development<br>• Setting priorities and measures for the development of research and innovation infrastructure at the university | | • Identification of opportunities to create strategic alliances with leading foreign universities, companies, research centers and scientists<br>• Selection of Russian and foreign partners for the development of S&T cooperation |
| **Scientific organizations** | • Analysis of the challenges, threats, problems and "windows | • Analysis and forecast of future market trends and technologies in the sphere of activities of the organization<br>• Creating an internal system of R&D priorities with a clear focus on the needs of large and medium-sized | | • Identification of opportunities to create |

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| | of opportunity" of global and national educational systems for setting the strategic priorities in the university development programs | businesses in Russia and abroad<br>• Evaluation of necessary competence profiles in the type of skills needed and time of their occurrence, working up appropriate measures to support their development | strategic alliances with leading foreign universities, companies, research centers and scientists<br>• Selection of Russian and foreign partners for the development of S&T cooperation |
| **The science and industry expert communities** | Formation of information agenda to create new regular events and update the existing thematic branches of conferences and seminars devoted to S&T; defining "white" spots on the expert competence map; systematically updating and developing knowledge of members of the scientific and professional communities; the development of international and domestic relations and communications channels | | |

## Conclusion

The defined and analyzed global trends in the 7 selected areas of S&T development are becoming increasingly important for drawing up STI policy and for identifying the promising markets and product groups in the interest of companies in the real sector of the economy. It should be noted that the trends discussed in various R&D fields are already interrelated which means that in the future many of the most successful technologies and innovative products will have a diffusing nature. This fact explains the extremely complex ongoing processes in the global economy and the scientific community, such as NBIC-convergence and the changing techno-economic paradigm. The key sectors of the world economy the development of which according to experts will be a top priority in the medium and long-term are the following: energy, oil and gas processing, petrochemical industry, mechanical engineering, information and communication systems, and transportation.

The main long-term socio-economic trends in these sectors have been defined as follows:

- general trend towards post-industrial development, displacing industrial "workshops of the world" from the global economy (the concepts of "developed country" and "industrialized country" are not synonymous any more, as it was in the mid-20th century);
- a tendency to preserve, at least in the medium-term, low cost as a major competitive advantage in mass production;
- rapid obsolescence of industrial production, the reduction of its life cycle time;
- achievement of the stage of maturity of the key industrial sectors of the 20th century inevitably accompanied by a slowdown in economic growth in the medium-term;
- growing trend towards localization instead of globalization (birth of “glocaliazation”);
- tendency towards "new industrialization" in developed countries, based on new technologies and organizational principles, focused on the creation and implementation of competitive advantages in the field of small-scale and even a single production.

The rends listed above point to the need to ensure a new quality of industrial growth largely based on the introduction and dissemination of the achievements of the priority research and development areas in the real sector of Russian economy. However, the efficiency of these processes depends entirely on the STI policy of the country and the ability of economic agents to innovate. In modern conditions the Russian culture of technology Foresight has become a major tool for conducting studies about possible trajectories of S&T development that allow to combine and coordinate the aims of the government, business and science in the search for the new sources of long-term growth. This is reflected in the formation of a national technology Foresight system and the development of the infrastructure and mechanisms that make possible systematic interactions between key stakeholders in the national innovation system and their participation in the development of national STI policy by the construction of legitimized and shared technological visions of the future economy.

Among other facts the modern tendencies in S&T Foresight-researches, which can be witnessed in many countries, clearly indicate a gradual "incorporation" of Foresight into the S&T policy-making system. At the same time – primarily as a result of the vigorous progress of the Internet – the Foresight researches are carried out using a wider range of informational resources and means for analysis, which creates a basis for the convergence of quantitative and qualitative methods. Nowadays Russia, according to many parameters of completed Foresight-researches rises to the level of foreign "fashion legislators" in this sphere. To enter fully the number of world leaders, two fields ought to be advanced: the creation of a stably functioning expert base, which covers all segments of the national innovation system, and strengthening the interaction between the main stakeholders in the framework of national technology Foresight system. All this will allow for the creation of auspicious possibilities for practical transformation of Foresight into an STI policy instrument, oriented towards a long term perspective.

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