Problems of introducing an integrated scientific development management system

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Abstract. To achieve the required quality of technology in the creation of new technology, an applied research management system is required. The purpose of the article is to identify problems and ways to solve them when introducing a complex new system in high-tech industries. The methodology includes a systematic analysis of sectoral scientific activities in strategic planning and forecasting the development of technologies and management of the creation of a reserve. The system is built on modern principles of technology development and scientific potential: programmatic and targeted approach, optimization of research in several areas and choice of one as the main research concept, assessment of the level of technical excellence, strategic and tactical planning to achieve the predicted result. An attempt is made to cover the whole range of problems of introducing an innovative system with the aim of general understanding of the strategy of its implementation, development of a methodology and program.

1. Introduction

To create new samples of complex technology requires innovation (new technologies, solutions, materials, etc.) at the stage of integrated design and production. In recent years, the need for scientific research has been proven to achieve the required level of technical perfection of the proposed innovations. "Saving" money and time for such work significantly increases losses at the subsequent stages of the product life cycle and reduces its characteristics. We need special management systems for the creation of scientific and technical reserve (STR) and localization of accumulated technologies. The need is caused by two circumstances: beginning of the sixth technological order and transition from the traditional (directive-sequential) to the innovative principle (multi-vector, optimization) of the creation of new technology.

Various aspects of creating STR are discussed. In Russia, models are being developed for financing the innovative activities of high-tech enterprises [1]. Models of a comprehensive technical and economic assessment of options for the joint use of new and traditional technologies for creating STR are investigated [2]. The research and development management system is studied based on technology readiness levels, program-target budgeting and target indicators [3]. A methodological toolkit is being developed to assess the technical and economic efficiency of the technologies being introduced [4].

Special systems are being developed to facilitate the generation of STR, for example, in general, a quality management system has been introduced at defense industry enterprises. New principles and methods of managing transport, logistics and industrial enterprises based on cyber-physical systems have been proposed by Russian and German scientists [5].

The development management methodology based on the levels of readiness of technologies at the tactical and strategic levels is promising [6]. The authors propose methods for assessing the effectiveness of technologies and their levels of readiness, as well as methods for selecting and ranking technologies and research projects. Such a system has been worked out in theoretical terms and its implementation is relevant. This is especially actually for aircraft industry, an industry that is on the verge of developing fundamentally new concepts, developing types of aircraft, engines and aircraft systems.

2. Theoretical basis

The system being implemented is built taking into account many years of experience in creating new technology: at the initial stages of development, scientific research is carried out in several directions, in the future, tasks and resources used are optimized along the chosen path [7, 8, 9]. First, the preliminary effect that future technology-products could bring to achieve the desired level of excellence is assessed; then the question of starting research is decided. The effectiveness of innovation depends on the degree of development of technologies in other elements of the system, on the timing of the "launch" of a new technology, on the forecast of the emergence of innovations in the external to the system environment.

The following basic concepts are used:

- STR is a set of new knowledge and technical solutions, on the basis of which technology development is possible;
- scientific research: activities aimed at obtaining and applying new knowledge: applied scientific research (aimed at applying new knowledge to achieve practical goals and solving specific problems) and exploratory research (focused on applied scientific research);
- comprehensive management system of Research and Development (CMS R&D) is a system for creating advanced STR, including problem-oriented and complex projects for integrated design and production of a product;
- CMS R&D implementation is the process of creating system elements within the existing organizational structures of an enterprise (institution, organization), training the involved staff to work in a new system (including new functions, incentives), setting up (testing) the system in typical research projects;
- level of scientific and technical excellence is an indicator of the technical excellence of technology at the stage of developing materials, components, devices, etc., including fundamental and exploratory research, design and technological solutions. It is confirmed by experimental or calculation methods.

3. Methodology

Various interests and their characteristics, understanding the institutional problems and obstacles in the implementation of STR creation system for high-tech products were considered. The study is based on an analytical and systematic study of industry research activities on strategic planning and forecasting of technology development and management of the creation of STR in the aircraft industry.

3.1. CMS R&D

One of the modern innovative systems, CMS R&D, is designed to create a leading STR product with specified properties and levels of scientific and technical excellence. It is assumed that it will allow settling the problems of delaying deadlines, increasing costs and failing to achieve the required characteristics of the sample and will become the leading system for creating new technologies for high-tech products.

CMS R&D was formed by The National Research Center "Zhukovsky Institute" [10] with an emphasis on achieving the predicted efficiency of technologies and providing the necessary scientific resources (staff and experimental base) for this. At the heart of CMS R&D is a program-targeted approach, modernized taking into account the contradiction between the planned work performance and the uncertainty of results inherent in research.

The system ensures the creation of STR from the technological level of “formulating and substantiating the idea of solving a problem” to the level of “demonstrating a prototype and proving the effectiveness of technologies in real conditions, the possibility of developing with the implementation of the required properties”. This means the possibility of conducting scientific research at the expense of state budgeting and the transition to commercial "mastering" of technologies at the levels of development work.

CMS R&D covers integrated forecasting of target areas of values of the level of scientific and technical excellence and the formation of strategic optimal plans for the development of technologies; tactical planning of scientific research, projects and their resource provision by stages. Structurally, it includes the following subsystems:

- parallel forecasting of the development of technologies (working on the basis of the requirements for the characteristics of promising technology at the level of target tasks) and predicting the attainable values of the possible characteristics of samples developed on the basis of various technical concepts;
- strategic planning of technology development: it forms an optimal strategic work plan, selection of technical concepts and assessment of the necessary resources of scientific potential and the cost and time of their development;
- strategic management of industrial science resources for optimal management of its potential; subsystem sets the requirements for the resources of science (experimental base, staff), based on plans for the development of certain technologies;
- short-term planning (programming) of work and development of resources (experimental base, staff) of science; subsystem works on the basis of strategic plans with monitoring of intermediate results to clarify the effectiveness of various technologies and technical concepts at stages;
- tactical management, specifying their effectiveness in assessing the level of scientific and technical excellence for making tactical decisions and adjusting strategic plans;
- managing the results of scientific and technical activities, including analyzing the possibilities of their transfer to other industries and areas of technology, keeping records of monitoring data from research and development in Russia and abroad.

CMS R&D inputs are parameters and indicators of strategies, programs and other strategic planning documents, as well as the amount of funding. Outputs are the level of implementation of the relevant parameters and indicators; results of scientific and technical activities (including those transferred to other industries and countries). The developed version of CMS R&D is adapted to generating STR of different types: in terms of the scale of the level of development, in the degree of complexity of tasks, in the type of management that affects the specifics of research, etc. from simple technology-rationalizations to transport and defense tasks on a national scale.

The proposed CMS R&D provides the receipt of STR for making a decision on the creation of a sample and the transition to design, construction, etc., which means both scientific research and scientific and technical activities. This involves the involvement of employees from different organizational structures and the creation of new divisions at the enterprise, in the institution.

3.2. Features of the transition to innovative systems for creating advanced STR

For the successful functioning of CMS R&D, certain external conditions are necessary: constant set of customer requirements throughout the entire period of STR creation, sufficient time (especially at the stages of forecasting the possibilities of developing technologies and concepts) and availability of research funding.

It is rather difficult to provide internal conditions, which include timeliness of the receipt of new results of fundamental science, availability of the necessary experimental, testing base and staff, ability to objectively rank and select problem-oriented and exploratory research, estimate the cost of technology development, take into account the mutual influence of applied technologies and exploratory research (including return to the previous stages based on updated data), possibility of diversification and integration of works, etc.

There are several main reasons for the need to implement innovative systems for creating advanced STR at enterprises and organizations:

- timing of manufacturing samples of high-tech products is disrupted. There are many reasons, but the main thing is the inability to manage the complex processes of creating an advanced STR. Modern method require parallel and multi-vector work in different directions, which contradicts the traditional (sequential, so-called design) approach to creating technologies;
- outdated technologies are used. As a rule, old technologies are familiar, tested, have a low risk of failure, they have waste documentation, production equipment, etc. New technologies may not work, do not give the expected effect, but show side effects, etc.;
- business leaders are accustomed to compensating for the lack of funding for development work by reducing research and development costs. In addition, quite often complex testing and experimental equipment for research work is idle due to the lack of professional staff or the need for research, and its maintenance or payment is expensive;
- consumers of civilian products cannot or do not want to switch to Russian products due to the high risks of disruption of supplies and services without guarantees from the state or large corporations. In practice, complex production processes are successful when there is an integration system, as it is in the case in PJSC United Aircraft Corporation, JSC United Engine Corporation, CJSC Transmashholding, etc.;
- state does not aim to support national industries (primarily aircraft construction). There is no understanding that budgetary financing of scientific research is an opportunity for the state in the future to reduce business risks in the implementation of experimental design work and in industrial production. The state should refuse to support narrowly focused projects in favor of large-scale and complex projects with the development of cooperation.

Implementation of the system is a complex task, it will require appropriate methods and programs for the process, organization standards governing the implementation of the system; developed and tested technologies for information and analytical support of project management and research monitoring based on the created model of the system.

3.3. Problems of CMS R&D implementation in aircraft construction

The works [9,10] are devoted to the issues of harmonizing the interests of all participants in the creation of STR and rationalizing the ways of making decisions on the development of technologies. However, the task of introducing a special management system has not yet been set, since there are many problems and obstacles that must be solved and overcome. Their groups can be distinguished:

1. Opposition of interests, requests, expectations:

1.1. inconsistency of interests, reflecting different understanding of the reform of applied science and the effectiveness of management of a high-risk area of scientific research. The corporate interests of the management of scientific organizations, which have their own long-term vision of development prospects, are of decisive importance. There are departmental interests and various authorities, to the extent of their powers, regulating the development of applied science and scientific institutions. The interests of different categories of workers also affect, but they can change over time depending on the scientific tasks solved by enterprises and organizations, financial and staff policy and other factors;

1.2. low interest of industrial organizations in funding applied research for the development of new technologies (due to high demands). It has the following sides: a) requirement for high-availability technologies; b) need to solve specific narrow issues in a short time (without taking into account scientific elaboration); c) requirement of high guarantees of obtaining technologies with given parameters. In addition, this interest is changing ambiguously as the economic situation of the industry tightens;

1.3. imbalance of expectations: on the one hand, scientists fear that an objective quantitative assessment of the usefulness of those technologies that they personally develop will lead to the closure of their own work as non-priority. On the other hand, there is a state interest in obtaining objective utility, which is expressed in different ways by leaders of different levels, different competencies and powers;

1.4. motivational differences: some "industry" scientists who have the opportunity to actually increase the productivity of their work and the usefulness of its results (thanks to more objective planning of applied research), do not resist innovation. Others, realizing that the work performed does not provide the level of scientific and technical excellence in the allotted time, strive to maintain the old system of scientific research;

1.5. problems of "conservative" and "revolutionary" consciousness in the period of technological breakdown of the old and new structures. Thus, the unattainability of strategic goals within the framework of traditional technologies is revealed, the need to implement breakthrough, radical innovations, the need to attract competencies from other industries, i.e. cross-sectoral integration. Potential performers of work traditionally belonging to the industry, possessing certain competencies, are not interested in attracting new ones, and, moreover, in replacing their competencies with third parties. "Flexible" scientists overcome the "dependence on the passed path" to become leaders in new scientific and technological areas.

2. Methodological unreadiness, lack of rules of conduct and standards:

2.1. unresolved issue of an objective assessment of the effectiveness of the directions of technological development (it depends on subjective positions (see paragraph 1.4)). Even in official regulatory documents, we can find different terminology: effectiveness, efficiency, etc. (for example, in the Budget Code). This indicator is seen in different ways at the stages of exploratory and problem-oriented scientific research, complex scientific and technological projects, experimental design work, etc., since it includes an unequal probability of achieving results (in public administration, it is simpler: there the probability is close to 100%). In addition, different specialists have their own understanding and interpretation of effectiveness, depending on his position and capable of changing over time as his competence grows;

2.2. problem of openness and transparency of relations between the customer and CMS R&D participants, in particular, in relation to the requested resources. Attempts to overestimate the cost and timing of the project in the short term can lead to strategic losses: customer reduces the costs of the most necessary work, abandons the project as a whole or transfers it to weak (scientifically) competitors. Affected by the long-standing long-term mistrust, non-obligation, irresponsibility ("multi-agency") of economic entities and authorities. Under the new conditions, strategic interests prescribe the state customer: a) to take into account the peculiarities and emerging difficulties in the high technology industry and applied science, readiness to satisfy their needs; b) to achieve mutual openness in relation to the cost and level of scientific and technical excellence;

2.3. problem of ordering procedures (trust and openness of relations) between project participants on the use of their own scientific resources (experimental, testing and instrumental base, as well as staff). We need a mechanism to stimulate participants to open information about the unevenness of resource requirements during the implementation of various stages of their projects. It is advisable to create a procedure for providing a scarce resource to any of the participants in a specialized "common resource center". Then everyone can be sure that he will get what and when he needs at the lowest cost. Otherwise, each participant is forced to demand the maximum amount of funds from his manager (Ministry of Industry and Trade, Ministry of Education and Science, Ministry of Transport, etc.), at the risk of getting less than necessary. An obstacle to elementary ordering is labor relations, according to which the employer is obliged to provide the employee with work evenly according to the labor function and to pay wages, including for forced downtime. Therefore, the employer seeks to optimize (on average, minimum) their costs. Thus, the orderliness of procedures can lead to the inclusion of an employee not only in labor, but also in civil (in this case, associated with staff risk) legal relations;

2.4. lack of a developed monitoring system for the management of scientific research on the part of the customer, which ensures guaranteed cost optimization at each stage for all participants. In the short term, it can save money by limiting the ability for others to increase the amount of allocated resources. But in the long term, this practice should lead to an increase in the total volumes of the requested resources and to the failure of any of the participants to reach the target areas;

2.5. ministries and the scientific community disagree on the role of applied science and its features. This applies, in particular, to the financing of management in the transition from relatively cheap fundamental scientific ideas to scientific research of applied science and prototypes, and then to technical documentation and high-tech products. There is not even a concept of "scientific and technical groundwork" in the legislative base. The difference in approaches must be overcome at the methodological level before it becomes an institutional problem.

3. Conservative mentality and motivation:

3.1. there is no motivation for researchers to implement a formalized management system for applied research. Even interest groups have a lack of confidence in the "performance" of such a system. If its implementation will increase the productivity of research and the usefulness of their results for industry, then scientists will feel material gains, despite additional efforts. At present, the cost of work assigned by the customer-purchaser for applied research is determined based on the current average duration of applied research and the usefulness of their results. Due to relatively objective assessments of the achievement of levels of scientific and technical excellence, uncertainty of the timing of achieving results, as well as their usefulness for implementation in industry, will decrease;

3.2. many scientists understand that the limit principle of funding science removes the issue of increasing labor productivity. (It can be solved when scientific research will be funded in accordance with the expected effectiveness of their results). Therefore, some managers and scientists may be interested in increasing the labor intensity of the theoretical and experimental work performed. They have no confidence in the implementation of the new system, in increasing the objectivity of the assessment of effectiveness, in the precise goal-setting, in the validity of the amount of their funding, etc. The experience of introducing various schemes of informatization in science and other spheres shows that at first there comes a period of confusion and numerous alterations, only then a positive effect will appear;

3.3. often, the formalized goal-setting of scientific and technological development is perceived as cutting off "unnecessary" works and directions, as a threat to one's own research and arouses the desire for self-defense. Mistrust increases during the transition to a new technological order, when the previous directions of development have already exhausted their scientific potential, and it is important to correctly assess which new directions and technologies may be the most promising;

3.4. state customer, seeking to save on purchases in the short term, from the established practice of distributing orders on a competitive basis, sets a price at the cost price level, without allocating funds for the development of the scientific base of the contractor. The heads of organizations become not interested in receiving such orders. In the long term, such a policy will lead to monopolization of the market and the departure of developing suppliers, a subsequent increase in prices;

3.5. absence of an objective quantitative assessment of the usefulness of the technologies being developed, an assessment of the expected performance of the work carried out will lead to a reduction in funding for all applied science from the Ministry due to the feeling that its development is futile. Until the results of applied scientific research and STR do not provide an increase in the level of scientific and technical excellence of products, the usefulness of scientific projects is not revealed.

4. Objective problems of the transition period of CMS R&D implementation:

4.1. institutional features of the external environment (enterprises, contractors, financing and control structures, etc.) have a decisive influence on the formation of tactical programs for applied scientific research, planning of specific scientific projects. For example, with regard to the employment of workers: on the one hand, each project implies certain stages of implementation, moreover, the required number of employees and the volumes of various resources they need, etc. can vary significantly at each stage. On the other hand, such an irregular distribution is inconvenient and unprofitable for the enterprise, since it is not clear how to change the number of employees and how to ensure a uniform workload;

4.2. instability of budgetary financing is caused by three-year budget cycles, adoption of various programs, strategies, projects that are filled from the state budget and regional budget and commercial funds. In such conditions, managers fear that by declaring lower needs at the initial stages, they will then not be able to justify the need to increase them at subsequent stages;

4.3. implementation of the proposed applied science management system is a laborious and step-by-step process. It includes the development, methodological and regulatory support for implementation that requires several years and the involvement of many external competencies. It can boil down to an organizational shake-up that will generate negative expectations among scientists. In addition, in the short term, the necessary increase in transparency will entail financial losses for scientists and research teams. At the same time, the volume of reporting increases, the proportion of time that has to be spent on management, routine activities;

4.4. there is no transparent information policy, no system of popularization of the developed management principles among scientists. People need to be trained in the new methods and procedures that they will have to apply in the new system. Employees should understand and realize the prospects for increasing the efficiency of their work from the point of view of state interests and the prospects for increasing their well-being;

4.5. in the plans for the development of applied science management, a special link is envisaged: role of state structures, financing and control functions are transferred to the competence centers of applied science. In accordance with the declared principles, it plans scientific research and activities for the development of scientific institutions and organizations, justifying the necessary amount of costs, the usefulness of the technologies being created. The centers help government agencies to perform the functions of a “qualified customer” in the field of applied research and development, and scientific institutions: to work more efficiently, from a government point of view, and in the long term to provide higher and more stable funding.

4. Results and discussion

CMS R&D model, which has been tested at The National Research Center "Zhukovsky Institute" and analysis of the features and difficulties of implementing CMS R&D in high-tech industries, is presented. The problems of introducing a new system for creating STR (innovative principle) in the structures of organizations and enterprises operating according to the previously established practice (traditional, design principle) were identified. The logic of the introduction of the scientific development management system to solve the identified problems has been substantiated.

The presented results are the product of analysis, synthesis, generalization of rather unsystematized data, and some of them require serious substantiation, rechecking at the level of deep sociological research. An attempt was made to cover the whole range of problems and difficulties in implementing an innovative system (such as CMS R&D) for a holistic understanding of the strategy, development of a methodology and implementation program.

5. Conclusions

The proposed CMS R&D is similar to the system operating in the field of creating product technologies based on monitoring their readiness levels. CMS R&D contributes to an increase in the level of scientific and technical excellence, research efficiency, development of a scientific resource, reducing costs and risks of not achieving target values. The implementation of the proposed CMS R&D or a similar system for creating STR is a necessary, but laborious and lengthy process that requires the involvement of external competencies, development of methods, organization standards and other regulations that take into account the peculiarities of its functioning. In an institution, enterprise, organization, the conditions for the functioning of the applied science development system (such as CMS R&D) must be taken into account for its successful implementation. Thus, a favorable external condition will be the creation of "centers of competence" of applied science, which can eliminate the previous shadow management mechanisms that are emerging between the leadership of a scientific institution and specialized executive authorities. Strategic planning for the development of technologies and the development of scientific potential can be improved: there is still a strong influence of potential performers on the setting of goals, which reduces the quality of goals (there is planning "from the achieved"). Ensuring the internal conditions for the functioning of the developed CMS R&D depends on the team's focus on the implementation of this system. Elements of management tools should be developed: systems of management, assessment, ranking of various potential-resources (material, intellectual, technical, financial, etc.). (For example, system for assessing the required characteristics of the experimental and polygon base and staff). The implementation of CMS R&D is associated with overcoming problems and obstacles, mainly of an institutional nature. This is the confrontation of interests, requests, expectations of scientists, administrators of institutions and enterprises; methodological unpreparedness, lack of rules of conduct, standards in the relationship between participants in scientific research; conservative mentality, motivation of scientists and leaders; objective problems of the transition period. The solution of problems is possible when they are realized at the highest state level and the scientific and industrial policy is adjusted; development of large centers of competence (or similar structures concentrating scientific potential); popularization of the developed innovative management principles among scientists and researchers, including teaching new methods and procedures; conviction of the leadership of organizations and institutions in the need for their structural changes and integration into a new system that will restrict their rights and give new opportunities.

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