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Methodology for the development of key technologies

A fundamentally new approach to the creation of the methodology for the development of key (critical) technologies is proposed. It is based on: system approach, financing diversification, risk sharing, and evaluation. The order of formation of the key technologies list is offered. It is shown that for the key technologies development it is expedient to attract non-budgetary funding. The structuring of key technologies is proposed. It is proposed to share risks between the customer of key technologies and their performer through public-private partnership. Attention is paid to reducing corruption risks.

Keywords: key (critical) technology; distribution of risks; public-private partnership.

Today the scientific and technological sphere has become the main arena of competition among states and the possession of so-called «key» or «critical» technologies is used as one of the important instruments of geopolitics. Such technologies are of key importance for expanding the capabilities of a state's defence capabilities and achieving the purposes of national security. Selection of key technologies is used to determine the priorities of scientific and technological development of states and military-technical policy and are crucial for the process of creating promising weapons and military equipment. Therefore, the development of national key technologies in such industrialized countries as the US, Japan and the European Union is carried out at the state level. In particular, in the EU countries, the Euclid program is being implemented; Germany and Japan are participating in the Delphi program.

In Ukraine, however, most enterprises remain technologically backward, and products are energy-intensive. Every year in Ukraine there is a growing shortage of the latest technologies of military equipment production, the need for closed cycles for the development and production of major types of weapons, the need for complete independence of production from the supply of equipment, components and materials from the Russian Federation. For many years, the establishment of closed technological cycles, the introduction of advanced technologies and other measures aimed at meeting the needs of the Armed Forces of Ukraine are being discussed. The purpose of the development of critical technologies is again determined. To this end, the task is to find the organizational and legal form, regulatory and other conditions for the creation and operation of a fund, dedicated for the development of critical technologies. At the moment, the issue of establishing the State Fund for the Development of Basic and Critical Technologies and supporting innovations in the defence industry is being considered. The names of fund projects are changing, and their effectiveness remains nil.

Given the importance of the development of key technologies in ensuring the scientific and technological security of states, their development is devoted to a large number of studies published by many scholars. Wolff van Sintern, an international consultant for McKinsey & Company, specializing in solving strategic management tasks, believes that one of the main tasks of the European Defence Agency (EDA) is to promote defence co-operation and strengthen defence technological and the industrial base of Europe [1]. To this end, Wolff van Sintern proposes to designate an effective focal point in key technologies for EDA to organize the necessary dialogue between Member States. Transparency and early cooperation on planned procurement projects are needed, but more importantly, a serious dialogue is needed about the future of European industrial prospects and capabilities that need to be supported and developed in Europe.

Gustav Lindstrom, Director of the EU Institute for Security Studies (EUISS), describing the prospects for developing a European Permanent Structured Cooperation (PESCO) European Program, emphasized: specific areas that will also require sustained attention are the possible security implications arising from advances in technology [2]. Twenty-five EU states have officially joined the PESCO military cooperation program, and it remains open to other states if they want to join.

Certain tendencies to such cooperation also take place in the Russian Federation. In particular, the renationalisation of the aerospace industry began in 2006, which marked the beginning of a new era in industrial policy. Previously, such industries as the aerospace industry and shipbuilding were considered too important to be left on the market, since 2006, Moscow started promoting partial privatization and encouraging partnerships with western aerospace companies. Foreign investment in capital and technology is seen as a catalyst for Russia's dominance in the global military and commercial aerospace industry [3].

In the paper [4] it is noted that in Ukraine, in fact, the concept of «critical technologies» is not defined, and no state support is provided for them, which is detrimental to national security. The authors propose the creation of a state system for the identification, evaluation and support of national critical technologies. According to the authors, critical technologies should be considered as high technologies that are of fundamental importance for maintaining national security or economic growth and requiring conservation and development.

The paper [5] considered the terminology and principles of the development of key technology lists in foreign countries and in Ukraine. It is noted that the definition of «key» technology and rating system for determining the position of a country varies from country to country. Among the factors taken into account when determining of key technologies lists, there are such as the impact on competitiveness, the environment, national security, quality of life. Sometimes key technologies are defined as generic technologies, that is, those that have potential for use in many industries. The key technologies list is usually developed for a period of 10 years.

In Ukraine, for two decades, efforts to develop key technologies have been repeated, and all the same years, the same mechanisms, principles and approaches are considered. And their use did not have any effect. Summarizing the basic principles and approaches that have been unsuccessfully used so far for the development of key technologies, one can identify the following problematic issues:

1. **Unsystematic measures**. Legislative draft laws only propose the sources of funding and the authority to manage these funds.

2. **Financing**. Funding was provided only from the state budget of Ukraine.

3. **Risks**. All risks associated with the development and implementation of key technologies relied only on the state.

4. **Evaluation**. There was always neglect to evaluate both the management of the technology development process in order to achieve the ultimate purpose and the evaluation of the degree of achievement of the end results.

In this work, we suggest ways to solve these problematic issues, which will enable us to approach the development of key technologies on an alternative basis, making maximum use of all possibilities of Ukrainian realities.

1. System approach

Definition of terms

Interpretation of definitions is very important for their correct understanding and application. For example, the French scientist Ren? Descartes said: «Use the right words, and you will deprive the world of half of misunderstandings.» And his compatriot philosopher Francois Marie Arue, known for the pseudonym Voltaire, before the conversation offered the interlocutors: «Before the discussion, let's agree on the terms.» An effective way to negotiate terms is to define them in legal acts. In Ukraine, there is some inconsistency in terms of the term «key technologies» among various scientific and industrial circles, as well as executive authorities, which is related to the lack of definition of this concept in the standards and regulatory documents.

The normative and terminological uncertainty of the «key» as a component of promising technologies, and thus the different interpretation of these terms makes it impossible to determine the key technologies list, as well as measures to preserve and develop such technologies for the defence of the state. There were several unsuccessful attempts to define the term «critical technologies». Obviously, the failure of these efforts is due to the lack of a common understanding of the underlying principles on which the development of critical technologies should be based. It was offered to define the term «critical technologies» to managers of industrial enterprises. But each of them understood this definition in his own way, based on the problems of survival of his own enterprise.

In many languages, the word «critical» is characterized by a «catastrophic accent» (such as in a state of crisis, dangerous); therefore, in Europe, the term «key technologies» is stated, for example, in France as technologies clues [key technologies] [6], and in Germany as Schlusseltechnologien (key or core technologies) [7]. The term «key technologies» is also used in intergovernmental cooperation programs in science and technology in the European Union [8]. Despite the name, the interpretation is always one thing – technologies that have a high potential for influence on national competitiveness and quality of life [9].

However, the US has a fundamentally different approach to technology development, as it is a superpower claiming global world advantage. Therefore, in the US, the term «critical technologies» is used, which include technologies with a significant prospect of guaranteeing the long-term advantage of US weapons systems [10].

Taking into account the European aspirations of Ukraine, its non-aligned status and semantics, it is proposed to use the term «key technologies» rather than «critical technologies» (the key – the one that opens the possibilities for mastering, managing something) as being more responsive to the content of technologies needed both for the defence industry of Ukraine and for other sectors of the national economy [5].

An important condition for defining the term «key technologies» is the formulation of criteria for assigning technologies as key ones. B. Bimber and S. Popper noted in their work [11] that, in order to consider technology as a key, the selection procedure should meet the three criteria defined below.

1. Political relevance – the technologies list should reflect the potential areas for political interference to make the result achievable. Special attention should be paid to research and development, commercialization, dissemination and implementation of results.

2. Clear separation – key technologies should be clearly distinguished from non-key ones. Do not include any advanced (popular) technology. Special attention should be paid to the level of combination of different technologies in order to avoid concealment of non-key technologies under the «key header».

3. Reproducibility – even those who do not directly participate in the definition of key technologies should be able to restore the procedures used to select them. The method used should be transparent, reliable and accessible to the public.

The mentioned criteria fully correspond to the conditions prevailing in Ukraine. It is also necessary to add a criterion that determines the availability of technology in the international market. In particular, if technology can be purchased in another state without being subject to any restrictions, then such technology cannot be classified as a key one.

In the paper [5], it is suggested for the general interpretation of the concept «key technologies» in the defence sector in Ukraine to use the following definition – technologies that provide the development of weapons, military and special equipment specimens that are capable of successfully counteracting foreign samples and cannot be guaranteed imported.

It would be useful to formulate additional criteria for categorising technologies as key; these criteria are integral (characterizing the technology as a whole) and partial (characterizing the individual properties of technologies).

Integral Criteria:

- technologies, the possession of which makes it possible to meet the certain tactical and technical requirements for the developed specimens of weapon;
- competitiveness, as an indirect indicator, indicating sufficient military properties of the developed specimen of weapon;
- significant improvement in the effectiveness of weapons. For example, in the United States it is considered desirable to achieve a threefold improvement;
- technologies, the application of which changes the forms and methods of armed struggle, as well as preparation for it.

Partial Criteria:

- directions of scientific research relevant to the defence industry of Ukraine and in which Ukraine has a world-class achievement;
- technologies, the possession of which will allow to create fundamentally new specimens of weapon;
- technologies, the possession of which makes it possible to achieve improvement of several indicators of tactical and technical characteristics of the developed specimen of weapon.

Taking into account the above criteria, one can formulate the following definition of key technologies: Key technologies – unique technologies, without which it is impossible to manufacture, operate or repair specimens of weapon, and which cannot be guaranteed imported during a special period.

Practical orientation

The most well-known organization involved in the research and development of key technologies in defence is the Defence Advanced Research Projects Agency (DARPA) in the United States (US). The scale of the DARPA agency's research is evidenced by their motto: «To cast a javelin into the infinite spaces of the future.» In the US, the government is often blamed for lack of practical focus on DARPA research and related corruption risks.

Does Ukraine have the means to work in the infinite spaces of the future? Obviously not! There are no opportunities for this, except for the United States. Implementation in Ukraine of projects similar to the DARPA projects will raise the attention of law enforcement agencies and society, which can block the successful advancement of such projects.

Given the geopolitical realities and the economic capacity of Ukraine to develop technologies that use budget funds, they must have a low scientific and technical risk, an obvious practical orientation for the Armed Forces of Ukraine and a close practical perspective. It would be inappropriate to spend public funds on the development of technologies that are not used in the production of products needed for Ukraine, even if these technologies are the most advanced in the world. For example, Ukraine is one of the few countries possessing technology of welding in space, but this technology is not used in practice. Therefore, its further development is inappropriate.

The development of key technologies cannot be a purpose, because technology itself is not needed by society. Technology is just a means of achieving the purpose. The purpose is a practical thing that is needed by society. In particular, before Russian aggression the need for the development of

Ukrainian armed forces was not felt; consequently, the Armed Forces of Ukraine degraded despite financial costs. At the moment, there is no need for the Armed Forces, in general, there is need for some capabilities to adequately respond to the known threats from the aggressor. There is a requirement for specific types of weapons and in certain amounts. Due to limitation of resources, it is possible to get some but not all of the weapons that are needed. Hence, a balance has to be struck between which weapons are acquired and which aren't. If the scarce resources are used to obtain several different types of weapons all at once, then in reality nothing will have been achieved. For example, if an attempt was made to acquire combat tanks, aircrafts, ships and rockets at the same time with insufficient resources, the end result would probably be acquiring less than the optimum number of the various weapons. This can lead to the fact that we get half the tank, half the aircraft, half the ship and half the rocket. That is, we really will not get anything, but the resources will be irretrievably lost.

It is important that purpose and wishlist are not confused. The purpose must be practical and achievable. Determining the purpose is inextricably linked with available resources because either a purpose is set that is dictated by the available resources or the latter are squeezed so that a given purpose can be achieved. The first path is achievable but may not be effective (i.e. the outputs may fall short of what is actually required). The second way requires a non-standard approach, but could open up great opportunities. Mahatma Gandhi described it as follows: find purpose, the means will follow.

Proceeding from the necessity of practical orientation of development of key technologies, the ultimate purpose should be the production of socially important products based on new technologies.

The order of formation of the key technologies list

The order of formation of the key technologies list is offered by a successive selection of technologies corresponding to the criteria of assigning technologies to the key ones for the production of each kind of defence products through certain stages.

1. To determine the nomenclature and characteristics of the arms that Ukraine plans to produce on its own.

2. To determine the technologies list, the possession of which makes it possible to achieve the specified characteristics of weapons.

3. To select from this list those that cannot be guaranteed imported during a special period.

The resulting list of technologies will be key to developing a specific armament nomenclature.

Structuring key technologies

The structuring of the key technologies is useful in determining the appropriateness of their development. It is proposed to structure key technologies by indicators that characterize the most important consumer qualities of the product that will be obtained on the basis of these technologies. For example, it would be advisable to structure key technologies in two directions – the first direction characterizes the assignment of technology to the field of defence, the second direction characterizes the level of technology impact on national security and defence. An option for such structuring is given in the *Table 1*.

Table 1

Multi-level system of technology priorities

	Defence technology	**Dual use technologies**	**General purpose technologies**
The 1st level	Technologies, the control of which affects the state of national security and defence (*means of protected control and communication, combat navigation systems, high-precision weapons, etc.*)	Technologies required for civilian use, but control of which affects the state of national security and defence (*information technology, etc.*)	Technologies, the control of which affects the state of economic and food security (*energy sources, agrarian technologies, transport technologies, etc.*)
The 2nd level	Technologies that provide the development of combat capabilities, combat support capabilities (*ammunition and other means of destruction, means of detecting an enemy, mine protection, etc.*)	Technologies that facilitate the creation and support of combat capabilities, combat support capabilities (*specialty products, optical technologies, special purpose materials, etc.*)	Technologies that preserve the environment, technologies of human development (*environmental technologies, educational and information technologies, etc.*)
The 3rd level	Technologies that provide creation of capabilities for logistics and technical support, capabilities for deploying troops (*tactical medicine, special vehicles, repair tools, etc.*)	Technologies that facilitate the creation and maintenance of capabilities in the field of logistics and technical support, deployment capabilities (*means of treatment and rehabilitation, power plants, technical diagnostic tools, etc.*)	Technologies that ensure the quality of life of the population (*regional transport technologies, medical, food technologies, etc.*)

Depth of forecasting

It is necessary to determine the depth of forecasting, or, in other words, the time period for which the development of key technologies is considered. Given the geopolitical realities, Ukraine's economic capability and radical changes in our society it is proposed to consider the medium-term

perspective. Namely, the period up to 5 years in accordance with the Law of Ukraine «On National Security of Ukraine».

2. Diversification of financing

Obviously, the development of key technologies requires significant financial resources, so it is important to determine the sources of their funding. To date, only one form of financing has always been considered – from the state budget: a state fund, a percentage of the proceeds from the sale of military equipment abroad or lending.

One of the ways for the development of military and dual-use technologies, to produce specific specimens (complexes, systems) of armaments, military equipment, and technological modernization of defence industrial production, is through the creation of a dedicated fund for the development of key technologies that would not only advance the scientific and technical capabilities of the state, but also enhance the organization and coordination of pure and applied research in the context of the military-industrial complex. But many years of unsuccessful attempts to create state funds for the development of key technologies in Ukraine have confirmed the futility of this idea. Such funds are detached from the real needs of the Armed Forces of Ukraine, and in the face of limited funding, their content remains problematic. Therefore, further action in this direction is inappropriate.

However, the problem of increasing the effectiveness of science and technology developments cannot be solved solely by increasing the amount of budget funding, which is directed mainly to the maintenance of scientific institutions, without taking into account the effectiveness of their scientific activities.

It is necessary to diversify research funding not limited to budget funds, since they are clearly not enough, and the share of the private sector of the Ukrainian economy is predominant. In particular, according to the Ministry of Economic Development and Trade of Ukraine, the share of net income from sales of private sector economic entities is almost 90% [12]. At the same time, the share of private arms suppliers is steadily increasing to meet the defence requirement of the state; in 2017 it amounted to 55% [13]. In the world, there have long been effective mechanisms for attracting private capital for public needs, and one of the most effective ones is public-private partnership.

In view of this, one way of securing additional funding for the research and development of key technologies could be to attract funding from private and foreign investors, as well as working capital of state-owned enterprises. Only a small part of key technologies need to be financed from the state budget alone – these are those technologies that directly affect the state of national security and defence and on which the Government must maintain full control – first level defence technology in accordance with *Table 1*.

The first level defence key technologies are those that are funded exclusively by government funds. Products based on these technologies should be produced and sold only at the request of the Government through relevant government customers. These technologies tend to be classified. Defence key technologies that directly affect the state of national security and defence should be categorised as key technologies of the first level. Means of secure control and communication, combat navigation systems, recognition systems, data encryption, information security systems, high-precision weapons, missile systems, etc. are examples of this category of key technologies.

The second level defence key technologies are supported by the government through partial financing from the state budget, which makes it easier for defence companies to develop these technologies and produce products. Products based on these technologies could be sold on the world market, but with the permission of the Government. These technologies may be classified. The defence key technologies that provide the creation of combat capabilities, combat support capabilities, security and survivability, intelligence capabilities, are appropriate to categorised as second-level technologies. In particular, ammunition and other means of damage, armour materials, means of detecting an enemy, reducing the visibility of objects, mine protection, etc.

The third level defence key technologies are created without the involvement of public funds, but are funded solely by private investors and working capital of enterprises. Products created by these technologies could be sold on the world market without restrictions by the Government. These technologies, as a rule, are not classified. The defence key technologies that provide creation of capabilities for logistics, technical and medical support, deployment and mobility capabilities, and training capabilities are appropriate to be categorised to key third-level technologies. In particular, means of tactical medicine, vehicles (ground, air, sea), power plants, repair tools in field conditions, simulators for warfare, etc.

Private Finance Initiative

The well-known British concept of the Private-Finance Initiative (PFI), the most popular form of public-private partnership (PPP), adopted in 1992 by the government of John Major, enables private funds to finance public sector projects including defence. PFIs are long-term contracts between a public sector department, like the Ministry of Defence (MoD), and a private company to deliver asset-based services. The MoD first defines its requirements and then a private company makes the necessary investment to deliver on those requirements in exchange for payments over the term of these contracts. In defence PFIs, the buyer (i.e. the MoD) does not specify the 'how' of services to be offered; that is left to the private company to work out. This arrangement, therefore, allows the seller (i.e. the private company) to implement innovative ways of delivering the requirements. And since the MoD does not pay the seller until the delivery of services (which meet the criteria set out in PFI contracts) begins, risks of cost and time overruns

are borne by the private company. However, not all risks are transferred to the private company as that could compromise value for taxpayers' money. Hence some risks (like design, construction and operation) are transferred to the seller, others (like inflation risk) are shared between the two parties and yet others (such as demand risk) are borne by the buyer. Since the investment required in these contracts is comparatively much larger than the yearly payments made by the buyer, it allows the MoD to secure a greater number of capabilities using its limited funds.

It is usually prohibitively expensive for the buyer to abandon PFI projects; hence if executed correctly, they become an almost guaranteed long-term source of income for private companies. Additionally, buyers do not directly interfere with the day to day running of the private sector partner, which allows the private company, to come up with innovative ways of contract delivery that could reduce its costs and boost its profitability.

Increase of budget efficiency of investments of the state is carried out on the value for money. This is achieved through the quality management of the project by the private entrepreneur at all stages of the life cycle of this project, as well as by the positive practice of risk management and innovation; a high level of performance by a private enterprise of contractual obligations for qualitative parameters of the object, its operational status, terms and value.

Limited budget funds for the development of key technologies can be offset by attracting funds from private investors through public-private partnerships in the form of a private financial initiative. It would be advisable to launch several pilot projects, the experience of which will accumulate and distribute in the future.

Saving on a scale

Some countries pursue the development of key technologies, even when subject to financial constraints. In particular, the European Defence Agency encourages defence cooperation among member states by supporting them in collaborative defence projects. These projects enable each participating state to concentrate its efforts only on certain areas of research/key technologies and produce products based on those technologies that satisfy not only its domestic needs but those of other EU countries as well. In this way, each EU country uses its limited public funds to research and develop some, but not all, of the key technologies and related products it requires. It can buy the others from other partnering states that have researched and developed them. Such a strategy enables to combine budget expenditures on the development of key technologies and save on the scale of projects and programs. Obviously, such a strategy would be appropriate to use in Ukraine. In particular, in cooperation with the European Defence Agency, in the projects and programs of which Ukraine has the opportunity to participate since 2015.

3. Risks distribution

The development of the scientific and technological sphere and, in particular, the key technologies involves the search for new ideas, their development and their application in the manufacture of products. There are many cases where new ideas seemed surprisingly realistic and promising initially, but even with generous funding, they could not be converted into practical results. The main reason is that scientific research is always a search of the unknown, therefore the development of the scientific and technological sphere is always accompanied by the risk of loss of time and resources. However, it should be noted that the successful realization of the new idea in the technological sphere provides mega profits and often serves as an impetus for other socially important areas of science, technology and production. Therefore, such a risk is often justified, but before investing in a new idea, it is necessary to determine risk distribution amongst the various stakeholders; for instance, who will bear the risks of its implementation, who will lose their resources in case of unsuccessful development of the idea. It goes without saying that the party that expects to benefit from the successful implementation of the idea has to be the one to take the risk.

Public-private partnership

As previously defined, the development of first level defence key technologies and their direct distribution directly affects the state of national security and defence, so they are only needed for the Government and the latter must maintain full control over them. Such control can be established through the requirement to develop and sell products based on these technologies only on request of the Government through appropriate state customers. Consequently, the benefits of the implementation of first level defence key technologies will mainly be received by the Government and their development is necessary to be financed only from the state budget.

Another thing is the defence technology of the second and third levels. These technologies provide the creation of combat and other capabilities, contribute to their creation and retention during the life cycle. Their development and distribution does not directly affect the state of national security and defence. They are needed for the government, but full control over them is not appropriate. Second level technologies indirectly affect national security and defence. The government should only have partial control over these technologies, so their developers and manufacturers of the products can benefit from the sale of products on the market. Thus, the Government and the producer will benefit from the development of second level technologies. Consequently, the risks of creating such technologies should be shared between the Government and the manufacturer. Therefore, it is inappropriate to finance them only from the state budget. For their development, only partial financing from the state budget is required, which will

make it easier for defence enterprises to develop these technologies and manufacture the production.

Third-level technologies practically do not affect national security and defence. Therefore, it would be inappropriate for the Government to control these technologies, and their developers and manufacturers of the corresponding products are free to independently choose the ways of commercial realization of these technologies and benefit from the sale of the corresponding products in the market. Thus, the benefit of the development of third-level technologies will mainly be obtained by the manufacturer. Therefore, the risks of creating such technologies should be borne by the manufacturer. For their development, financing from the state budget is not required, and their development should be carried out solely at the expense of investors and working capital of enterprises.

Such a financial diversification of key technologies in terms of the impact on national security and defence can reduce the risks of the Government in the process of their development.

Therefore, it is expedient to finance the process of creating key technologies in Ukraine in the form of a mixed public-private partnership, which will allow to separate risks between the Government as a customer and the enterprise as a developer. At the same time, the Government's risks in case of negative results of research are reduced.

One of the ways of public-private partnership is the conclusion of forward or futures contracts, in which the contractor is obliged to develop a specimen of weapon at his own expense, and the customer is obliged to purchase a predetermined number of units of this specimen if its characteristics meet the technical requirements, approved by the customer. Minimum procurement volumes, their cost and technical requirements are agreed upon conclusion of the contract. It is advisable to conclude this type of contract with enterprises that develop defence key technologies that are categorized as second and third levels according to Table 1.

Reducing corruption risks

Transparency International, the international anti-corruption organisation, has developed the Government Defence Anti-Corruption Index, which defines the level of corruption risks in the state defence sector around the world. Ukraine, according to this index, is characterized as a «high risk» country. Therefore, reducing corruption risks is a distinct challenge in the process of development of key technologies. This is because when the Government enters into contracts with other parties for the development of key technologies, there is a risk that the government official who signs off such contracts could choose the wrong contractor due to conflict of interest or a so-called «kickbacks».

The World Bank (Washington), in its research findings, «The Many Faces of Corruption» [14] describes kickbacks as a form of a bribe where there is a return of cash to a public official who decides on their expense. The World Bank calls «kickback» as one of the most common types of corruption in the world; it can occur in the monetary relations of organizations of any form of ownership, but the biggest problem is the «kickback» in the public procurement system [14].

The easiest form of kickback is the transfer of funds to the head of a public institution or his relative from the contractor that has entered into a contract with the state. In particular, corrupt public officials often use front or shell companies, through which they hide the unlawful influence on the process of selection of contractors. The general scheme of this form of kickbacks, according to the World Bank, is shown in *Fig. 1* [14].

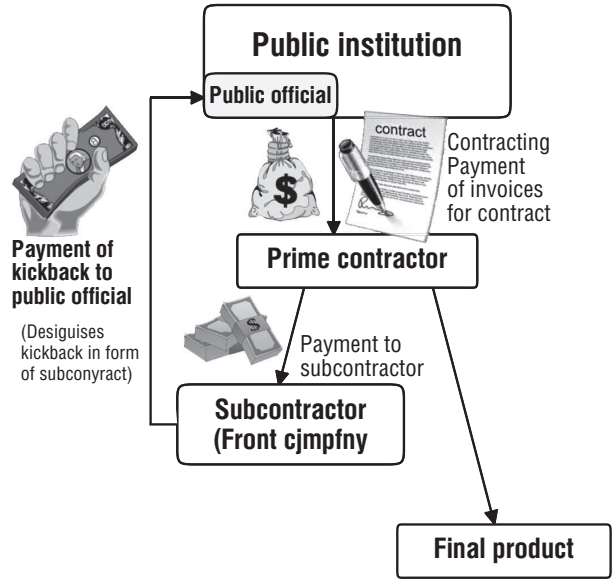

Fig. 1. General kickback scheme

The analysis of this scheme shows that the beginning of payment of the contract and the beginning of its implementation occur almost simultaneously. When entering into forward or futures contracts, the corrupt sequence of payment of the contract will be terminated, as shown in Fig. 2. In this case, the contractor will receive payment for the contract only after fulfilling his obligations under the contract. Such a form of contract is possible in the field of development of key technologies, as well as in other fields, which involve the receipt of scientific and technical result, including for carrying out research and development works.

4. Evaluation

For evaluation, the following statements are known: «If you can measure it, you can manage it»; «What gets measured gets done».

The first statement indicates the need for evaluation to manage the process in order to achieve the ultimate goal. Proceeding from the necessity of practical orientation of

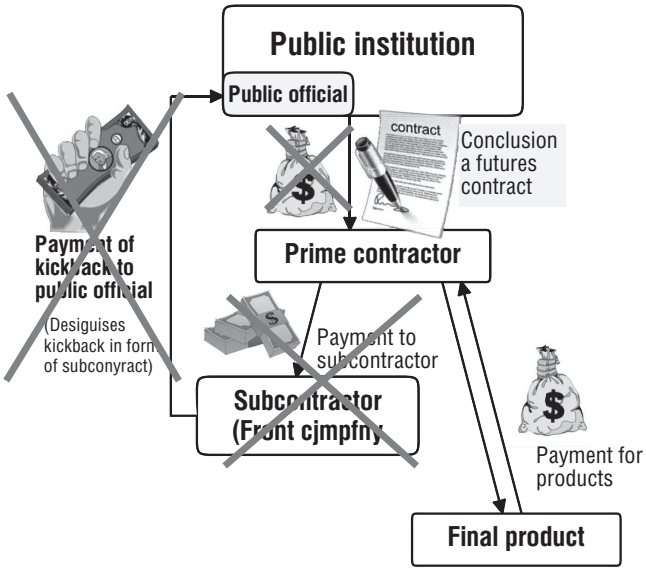

Fig. 2. General scheme of the break (change) of the sequence of payment of the contract

development of key technologies, the ultimate goal should be the production of socially important products based on new technologies. That is, an evaluation of feasibility.

The second statement indicates the need to evaluation the degree of achievement of the end results. That is, the evaluation of effectiveness.

Evaluation of feasibility

Prior to financing the development of technology, it is necessary to evaluate its relevance, as well as the possibility of implementing technology in production in the conditions of modern Ukraine. The most revealing is the reflection of the results of such an evaluation in the diagram «Importance of development» – «Ease of implementation», built on the basis of the method of discrete definitions. Such a diagram provides an opportunity not only to evaluate its feasibility in the conditions of modern Ukraine, but also to identify measures to promote the development of this technology.

Evaluation of effectiveness

The effectiveness of the development of technology is the degree of achievement of the final results, that is, the correlation between the actual and planned performance. An evaluation of the effectiveness implies getting the answer to the question of whether the intended goals were achieved and how the final results of the technology development correlate to the planned ones. An important element of the reliability of such an evaluation is the maturity specimen or the completeness of technology. The organization of production and implementation of the final socially important products based on this technology should be considered as the most reliable estimate of the effectiveness of technology development.

Evaluation of life cycle

Proceeding from the necessity of practical orientation of key technology, the most adequate evaluation of it is the elaboration of its life cycle, its value, definition of end products in which this technology should be implemented; forecasting volumes of production, their competitiveness, the possibility of organizing production in Ukraine, and other issues related to the implementation of the life cycle of technology.

The life cycle of each key technology for the defence industry should be worked out for a specific specimen (complex, system) of armament and military equipment and technological modernization of industrial production. If the technology allows the improvement of several specimens of weapons, then the one that is planned to be produced in the first place is being worked out.

Conclusions

As a result of the analysis of the experience of developing key (critical) technologies in Ukraine, the main mistakes that caused the negative result are shown. In this article, we suggest solutions to problematic issues that will bring us closer to the development of key technologies on an alternative basis, making the most of all the possibilities of Ukrainian realities. The basis of the proposed methodology is the following principles: system approach, financing diversification, risk sharing, evaluation. The order of formation of the key technologies list is offered. It is shown that for the key technologies development it is expedient to attract non-budgetary funding. The structuring of key technologies is proposed. It is proposed to share risks between the customer of key technologies and their performer through public-private partnership. Attention is paid to reducing corruption risks.

Let's show the main conclusions:

1. Within the framework of military-technical cooperation, it is advisable to combine budgetary expenses of Ukraine aimed at developing key technologies with similar expenses of partners, in particular, the European Defence Agency.

2. It is necessary to formulate criteria for assigning technologies to key ones and formulate a list of key technologies in accordance with these criteria.

3. The following definition has to be considered the most appropriate one: Key technologies are technologies without which it is impossible to manufacture, operate or repair specimens of weapon and equipment and that cannot be guaranteed imported during a special period.

4. The funding for defence research aimed at the development of key technologies needs to be diversified, not limited to budget funds. It is advisable to attract funds from private and foreign investors for the most part of key technologies, as well as working capital of state enterprises.

5. Research on the development of key technologies in which budget funds are spent should have low scientific and

technical risks, obvious practical application for the armed forces and close practical perspective.

6. A list of key technologies needs to be formed through the sequential selection of technologies that meet the criteria for assigning technologies to the key ones for the production of each type of defence product through the proposed stages.

7. It is necessary to structure the key technologies by distributing them in two directions – the first direction characterizes the assignment of technology to defence, the second direction characterizes the level of technology impact on national security and defence.

8. It is proposed to share the risks arising from the development of key technologies between the Government as a customer and the enterprise as a developer through the implementation of public-private partnerships. In particular, this can be realized through the conclusion of forward or futures contracts, in which the executor is obliged to develop a specimen of weapon at his own expense, and the customer is obliged to purchase a predetermined number of units of this specimen if its characteristics meet the technical requirements approved by the customer. Minimum procurement volumes, their cost and technical requirements are agreed upon at the conclusion of such a contract.

9. A particular problem in the development of key technologies is the problem of overcoming corruption risks. It is shown that when entering forward or futures contracts, the corruption sequence of payment of the contract will be terminated.

10. The development of key technologies should be carried out in view of their practical application in the production of products necessary for the defence of Ukraine. When investing in key technologies, it is necessary to work out their life cycle, identify the final products in which these technologies should be implemented, the projected volumes of production, their competitiveness, the possibility of organizing production in Ukraine and other issues related to the implementation of the life cycle of technology.

11. An important element in the success of the development of key technologies is the evaluation. It is necessary to evaluate the feasibility of technology in terms of its life cycle, which will allow successful management of the process, directing it to the production of socially important products based on new technologies. It is also necessary to evaluate effectiveness, which will determine the degree of achievement of the end results of each stage, as well as the maturity of the technology.

In further research in this area, there's a need of analytical studies conduction, aimed at detailing the methodology developed in this article on the development of key technologies, including: terminology, system approach, financing, risks, practical orientation and other relevant aspects for this area.

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