PROGRAM-TARGET APPROACH TO THE FORMATION PLANS OF RESEARCH, DEVELOPMENT AND PRODUCTION OF COMPLEX TECHNICAL AND HUMAN-MACHINE SYSTEMS

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Abstract. **The paper reviews the approach to the formation long-term plans of research, development and production in industry-based target predictions of the life cycles and end-to-end plans for future complex technical and human-machine systems (CTS, HMS), the idea of which was suggested in [1]. The main role in the planning process is played by the system of interconnected matrix «means-end», which provides a systematic approach in the formation of plans.**

Keywords: **plan, science, technology, planning, complex technical system, human-machine system, research, development of equipment, serial production, matrix «means-end».**

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1. INTRODUCTION

Depending on duration of planning period distinguish short-, medium- and long-term planning. When planning development of science and technology in our country short-term plans are annual plans, mid-term – five year, and long-term, plans that are designed for periods spanning several five-year plans. These types of plans differ not only in timing but also in content.

For example, consider plan of manufacture of samples of technics of any industry. When short-term planning is planned to manufacture the range of samples of techniques, installed at the beginning of the year. In the medium-term planning planned production samples of techniques with new, technically feasible characteristics. This means that sphere of medium-term planning includes the planning of R&D, preparation of production and capital construction. Long-term plan is promising and problematic in the sense that it is planned to produce samples of techniques that seem promising from the point of view of today, but development and production is a problem (problems). In the field of long-term planning includes all phases of the life cycle of new machinery, starting from the study idea of perspective sample to serial production.

Thus, only in long-term planning is the ability to perform end-to-end planning and management of development samples of new equipment, from study design to serial production and maintenance [2]. On the basis of long-term planning is the integration of science and production. Long-term plans serve as the basis for the formation of medium and short term plans, resulting in the quality of the latter significantly enhanced by making them target-oriented. Long-term planning should be with study many alternative options. It is impossible without a wide application of system analysis, methods of operations research, economic and mathematical methods and computers. In addition, it should also be noted that long term plans should be sliding, i.e. is to be corrected in 2-3 years. The sliding nature of long-term plans suggests that the relevant services are continuously made forecasts that precede these plans. For example, in the field of science, technology, economics, development of the external world, etc.

2. CREATION AN ARRAY OF TARGET PREDICTIONS, LIFE CYCLES AND CROSS-CUTTING PLANS OF COMPLEX TECHNICAL AND HUMAN-MACHINE SYSTEMS

Consider what needs to happen to develop long-term plans of scientific research, development and production of complex technical and human-machine systems (STS&HMS) in relation to mechanical and electronic instrument-making industries on the example of weapon systems (armaments) and military equipment (*AME*). The global challenges of the Armed Forces (protection of the state in nuclear-missile war, protection of the state in non-nuclear war, etc.), eventually deployed as calculated combat tasks, i.e. task that oriented on armaments and military equipment. *AME* complexes produced by each industry, are intended to solve a variety of computational combat missions:

$$P(t) = \{p_1(t), p_2(t), \ldots, p_n(t)\}, \quad (1)$$

which is a function of time t (p_i – a single task or element of the set tasks).

Each task of the set $P(t)$ makes demands for AME, with the help of which they can be resolved. Since some tasks will require the creation of new complexes, on the basis of this are formulating a set of tasks to develop their target forecasts of life cycles. After the implementation of the projections is formed an array of target predictions of the life cycles advanced systems of military equipment $V^*(t)$. The forecasting process must be continuous. Jobs for forecasts should be developed periodically (e.g., annually). Also periodically should occur replenishment and updated (adjustment) of the array of target predictions of the life cycles of advanced systems of weapons and military hardware. Each target forecast of life cycle of complex *AME* have multi-alternative nature and their number in array must always exceed the number that is in accordance with the financial restrictions can be included to a long-term plan of release complexes of *AME* for relevant industry sector.

An array of target predictions of the life cycles of advanced systems of *AME* indicates the potential of science-technical progress in the industry in terms of creating new complexes of *AME*.

When forming long-term plans of scientific research, development and manufacture of complexes of *AME* for industry sector you must choose from many target predictions of life cycles such subset of $V(t) \subset V^*(t)$ that, on the one hand, there is the best way in solving the problem (1), and on the other, met the financial limit on orders for scientific research, development and production. In the process of creating complexes of *AME* an array of target predictions of life cycles $V(t)$ also serves as a base for formation of the totality of their cross-cutting plans of $W(t)$ that contain all necessary information for compilation of relevant medium-term plans

An array of target predictions of the life cycles advanced systems of *AEM* $V(t)$ and a set of cross-cutting plans of $W(t)$ are the basis of program-target planning and management of scientific and technical progress in each industry (**Fig. 1**). Relevant decisions in the planning year are accepted, based on the tasks $P(t)$, considering both financial constraints and scientific-technical and production capabilities. Obviously, to evaluate these opportunities is only possible by carrying out various optimization and balance calculations using computer. Thus, program-target approach to planning and management of scientific and technical progress in industry

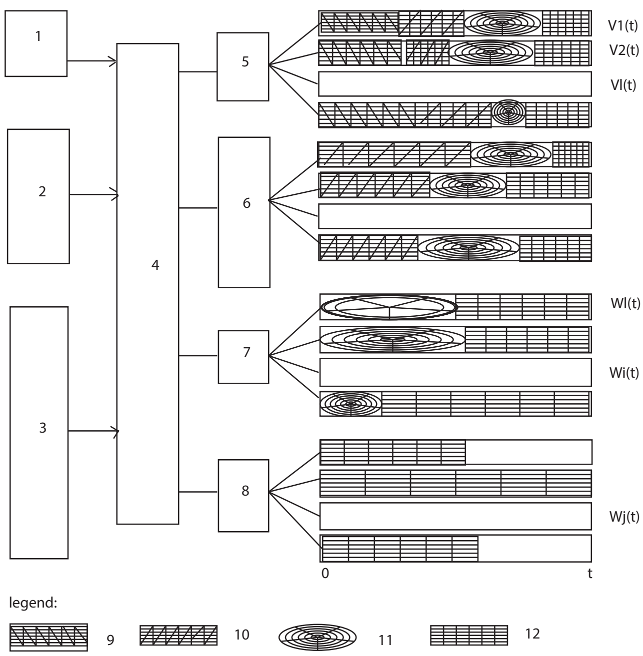

Fig. 1. *Scheme of program-target planning and management of scientific-technical progress in industry. Here: 1 - goals and tasks of the armed forces; 2 - directions of development of AME; 3 - appropriations for researches, developments and production; 4 - decisions taken a year of planning; 5 - about the beginning of the target scientific researches; 6 - about the beginning of the development of technical proposals; 7 - about the beginning of the R&D; 8 - about the serial production. Legends: 9 - target scientific researches; 10 - development of technical proposals; 11 - R&D; 12 - serial production.*

ensures alignment of the plans of development of science and technology with the plans of production, capital construction and logistics.

3. DEVELOPMENT AND ANALYSIS OF MATRICES "GOALS-MEANS"

When forming long-term plans of scientific research, development and manufacture of complexes of military equipment need to factor mutual usefulness, when one set W is used for solving several computational combat tasks or one task is solved with the help of a few complexes, when for applied research required the results of several fundamental research, or the results of fundamental research can be used in several applied studies, etc.

The relationship between the calculated combat tasks, complexes of military equipment, developments, applied, fundamental and exploratory researches can be set using matrices "goals-means".

Under the matrices with that name refers the certain tables, allowing to establish the structural and quantitative relations of the expert character, between some set of objectives (goals) of Y and set of means X by using which, according to experts, can be solved these tasks.

Let sets X and Y be in some way ordered and consist, respectively, of the m tools and n tasks. Note that in the general case, one or the other means x_i ($1 \leq i \leq m$) can be used to solve more than one task from the set Y, and one or the other task y_j ($1 \leq j \leq n$) can be solved by several different means of the set tools X. Therefore, when forming the matrix of "goals-means" first of all, there is the question of identifying subsets of problems $Y_i \subset Y$ that can be solved using the tool $x_i \in X$.

Subsets of Y_i for new means $x_i \in X$ are formed mainly by experts on the development of means-solving tasks from the set Y. If, for example, the set Y – the set of calculated combat tasks and x_i is a new complex of AME, then for determine the subset of Y_i by experts of an appropriate profile are specialists in the development of complexes of the type *AME* to which refers complex of x_i.

With regard to available funds x_i, then in this case in the formation of subsets Y_i prominent role is played by experts in solving problems, since it is in the process of practical use of funds identifies its valid potential.

It should be noted that when forming the subsets Y_i by experts can occur the idea of more broader use of funds $x_i \in X$, that ultimately may lead and leads to expansion of a plurality of solved tasks in relation to the original set Y.

After the formed subsets of Y_i, we can write the matrix of "goals-means" $H = ||h_{ij}||_{m,n}$, which displays installed by experts the structural connections between sets X and Y (**Fig. 2**). For means x_i ($1\leq i \leq m$) elements of the matrix H are defined as follows:

$$h_{ij} = \begin{cases} 1, & \text{5A; 8 } y_j \in Y_i, \\ 0, & \text{5A; 8 } y_j \notin Y_i. \end{cases}$$

Using matrix H, in turn, you can form a sets tools

$X_j = \{ x_i \in X \mid h_{ij} = 1, (1\leq i \leq m)\}$

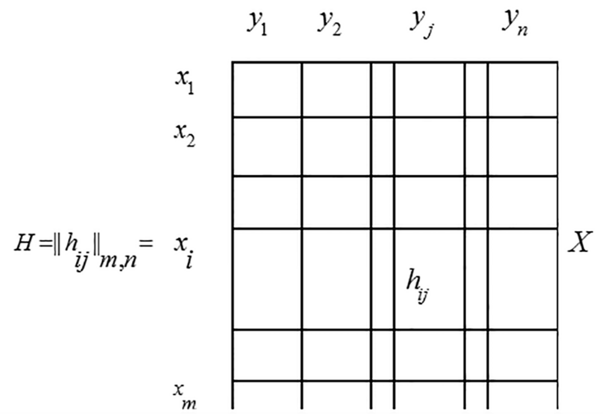

Fig. 2. *Matrix of "goals-means"*

each of which allows to solve the problem.

Identified structure of relations between sets of means X and goals Y allows you to jump to the definition of quantitative relations between these sets, to evaluate the effectiveness of application this or other remedies to solve the problem. Experts in this matter are mainly experts in solving problems, which, considering the capabilities of each available means to solve the problem, yj, evaluated at any of the accepted units, the effectiveness of this tool.

Let us consider two simplest examples of determining the effectiveness of funds in relation to the task. Let Y be the set of calculated combat tasks and X is a set of complexes of military equipment, which providing solutions to these challenges. Then as a measure of efficiency of use of the complex W $x_i \in X_j$ for the solution of the problem y_j can, for example, take the value of $1/k_{ij}$ or $1/c_i k_{ij}$, where k_{ij} is received by an expert way the estimate of the number of units of complex W x_i for which needed to solve the problem, y_j, and c_i is the cost of this complex.

Another example. Let Y be the set of mathematical problems, that require of numerical solution, X be a set of existing algorithms of their solution and let the algorithm $x_i \in X$ allows to solve the problem $y_j \in Y$. Then as a measure of efficiency of application of the algorithm x_i to the task of y_j can take a value of $1/\tau_{ij}$, where τ_{ij} is obtained by an expert way the estimate of the time, which required by some computing device, to receive the solution of the problem y_j using this algorithm. Naturally, when evaluating different algorithms from the set X in this case, the experts should focus on the same computing device.

Processing of expert evaluations of the effectiveness means of X relative to tasks Y allows to form a matrix of "goals-means" $H = ||h_{ij}||_{m,n}$, whose elements are defined as follows: $h_{ij} = 0$ if means x_i does not allow to solve the problem y_j, otherwise the elements $h_{ij} > 0$ and characterize the effectiveness of the means of the x_i in relation to the y_j task. In addition to the characteristics of the effectiveness of means X, the elements hij > 0 of matrix N may bear another meaning. For example, for complexes AME, the value of h_{ij} may indicate in which phase of the life cycle is the complex $x_i \in X$.

Thus, the matrix H gives a clear idea, with what means is possible solve any task from the set Y, and how each tool is used for solving several tasks. In the process analysis of the matrix "goals-means" you may find for some tasks in the set X two results: or there is not the means of solution, i.e. the corresponding set X_j is empty, or the available tools do not provide the sufficiently effective solutions to these problems. Then for the successful solution of all tasks from the set Y, you must find or create at least one more tool to help you to solve the problems, unsecured or poorly secured represented in the set X means.

Let us now return to the *formation programs of orders for AME*. Matrices "goals-means" allow to establish links the expert character, between the calculated combat tasks, the set of complexes AME, which needed to solve these problems, and the set of applied, fundamental and exploratory researches, that ensure these works. In addition, these matrices are convenient for systematization and extending the set of calculated combat tasks and the means of solving them.

Let us denote the matrices "problems–complexes AME" through $\Gamma^*(t) = \left\| \gamma^*_{ij} \right\|$. Since $t = 1, 2, ..., T$, then the matrix is constructed for each year t of the planning period T. Each column of the matrices $\Gamma^*(t)$ corresponds to the element of the set of problems (1.1), and each line – element is $q^*(t)$ the set $Q^*(t)$ AME complexes, i.e., $Q^*(t) = \{q_1^*(t), ..., q_m^*(t)\}$. All non-zero elements $\gamma_{ij}^*(t)$ in the j-th column indicate the totality set of AME complexes, that can be used when solving the j-th task. All non-zero elements $\gamma_{ij}^*(t)$ in the i-th line indicate possibility of using of j-th AME complex in a solving of number of combat missions (missiles and aircraft to various branches of the Armed Forces, managed anti-tank shells and missiles for air combat, etc.). In addition, the element $\gamma_{ij}^*(t)$ depending on accepted values may indicate the condition of the complex AME: in stage of production and operation or one of the other phases of the life cycle (conducting targeted research, development of technical proposals, etc.).

Analysis of the matrices $\Gamma^*(t)$ indicates which calculated combat tasks $P(t) \subset P^*(t)$ is bad or quite not provided with *AME*. It is a decisive factor in the choice of many developments (*R&D* or development of technical proposals) $Q(t) = \{q_1(t), ..., q_m(t)\}$ and the matrix formation of "task design", which we will denote by $\Gamma(t) = ||\gamma_{ij}(t)||$. Every nonzero element $\gamma_{ij}(t)$ indicates the relationship between problem $p_j(t)$ and the development of $q_i(t)$.

Obviously, not all developments can be touched for applied scientific research. For the possibility to start some developments $Q^*(T) \subset Q(t)$ must be previously obtained results of applied research. The relationship between the developments of $Q^*(t)= \{q_1^*(t), ..., q_m^*(t)\}$ and applied research $R(t) = \{r_1(t), ..., r_l(t)\}$can be expressed using matrices "design–applied research", which we denote $B(t) = ||\beta_{ij}(t)||$. The elements $\beta_{ij}(t)$ in these matrices play the same role as the matrices $\Gamma(t)$.

Goals for matrices $B(t)$ – the sets $Q^*(t)$, the means - the sets $R(t)$. Note that the objectives of the applied research can be not only the sets $Q^*(t)$ arising from task $P(t)$, but and a set of goals posed by the researches itself. Achieving these objectives will allow us to solve new class of problems not contained in the original set $P^*(t)$. This fact reflects the initiative of researchers, which offering new targets, and leads, consequently, to the extension of columns and rows of the matrix $\Gamma(t)$.

As a rule, the basis for applied research are the results obtained when carrying out fundamental and exploratory research. Obviously, not all applied research at time t can be performed without first conducting fundamental and exploratory research. Applied research is grouped for military-technical problems. Every military-technical problem can be seen as a goal to conduct fundamental and exploratory research. Herewith one military-technical problem is often solved as a result of the many fundamental and exploratory research conducted by various scientific fields. Fundamental and exploratory research may be conducted also to address several military-technical problems.

Having a list of military-technical problems of $R^*(t) = \{r_1^*(t), r_2^*(t), ..., r_n^*(t)\}$ and a list of scientific directions of $S(t) = \{s_1(t)\ s_2(t), ..., s_k(t)\}$, we can construct the matrix $A(t) = ||\alpha_{ij}(t)||$, the columns of which correspond to the technical problems and the lines of scientific areas. At the intersections of rows and columns of these matrices formed a list of fundamental and exploratory research carried out in this scientific direction in the interests of solving specific military-technical problems, as well as elements $\alpha_{ij}^{\xi}(t)$ ($\xi = \overline{1,k}$, where k is the number of research projects list), the values of which can characterize the importance of scientific research. Thus, each element $\alpha_{ij}(t)$ of the matrix $A(t)$ contains semantic and quantitative information about the fundamental and exploratory research conducted for the i-th direction, in order to solve the j-th military-technical problems.

As already noted, in the process of formation of a chain

$$\begin{array}{ccccccc} P(t) & \rightarrow & Q(t) & \rightarrow & R(t) & \rightarrow & S(t) \\ & G(t) & & B(t) & & A(t) & \end{array}$$

there is an expansion of all participating sets is due to the initiative of researchers, who believe that their research results will allow to solve a new class of combat tasks. In other words, the initial set of calculated combat tasks $P^*(t)$ arising from the tasks of the Armed Forces, is expanded due to proposals and inventions of scientists and engineers. As a result of these two information processes from top-down – from problems to science, and bottom up – from science to the tasks, are finally formed the lists of $P(t)$ - $Q(t)$, $R(t)$, $S(t)$ and of matrix $G(t)$ - $B(t)$ and $A(t)$.

The initial lists of developments, applied, fundamental and exploratory research, as mentioned, can be obtained as a result of the deployment targets the creation of each new complex of *AME* at number of subgoals, i.e. based on the target projections of life cycles complexes of *AME*. In **Fig. 3** is given a visual representation of this procedure, as well as the relationship between sequences of matrices "goals–means" $A(t)$, $B(t)$ and $G(t)$ for the one year. These matrices should be periodically adjusted in connection with the emergence of ideas about the development of advanced systems of weapons and military hardware.

Note that at the stages of forecast, negotiation with customers, etc. the lists $P(t)$, $Q(t)$, $R(t)$ and $S(t)$ have always the larger volume than those lists that can be included in the plans. Therefore it is necessary partially touch on the question of the criteria these lists for work plans.

Let the elements $\alpha_{ij}\xi(t)$, $\beta_{ij}(t)$ and $\gamma_{ij}(t)$have quantitative values reflecting the degree of importance of i-th means to achieve j-th objective. So, if we take the matrices $\Gamma(t) = ||\gamma_{ij}(t)||$, then here it is essential to determine the importance (preference) of each development $q_i(t)$ when solving each calculated combat tasks $p_j(t)$. For matrices $B(t) = ||\beta_{ij}(t)||$ you can talk about different significance of each applied scientific-research work $r_i(t)$ for the development of $q_j^*(t)$. Considering the matrix $A(t) = ||\alpha_{ij}(t)||$ can also indicate the importance of each fundamental or exploratory scientific research in solving each military-technical problem. Thus, the elements $\alpha_{ij}\xi(t)$, $\beta_{ij}(t)$ and $\gamma_{ij}(t)$ can be regarded as the coefficients of the contribution, importance or preference. The values of these coefficients can be obtained, in particular, as a result of a survey of experts in the relevant fields of science, technology and national economy. Knowing

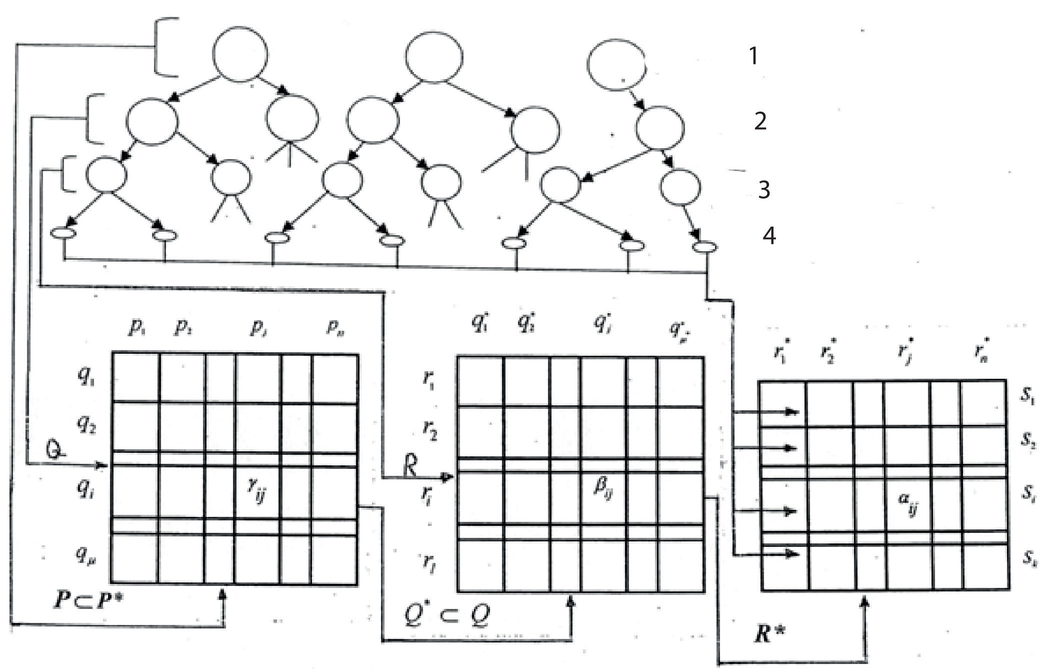

Fig. 3. *Formation of plans of scientific research and developments of AME complexes using matrices "goals-means". Here: 1 — tasks BC — $P \subset P^*$; 2 — P&D — Q; 3 — applied researches; 4 — fundamental and exploratory researches.*

the numerical values of the coefficients of importance $\alpha_{ij}\xi(t)$, $\beta_{ij}(t)$ and $\gamma_{ij}(t)$, we can estimate the relative importance or the preference in data or in the predicted conditions of the relevant developments, applied, exploratory and fundamental researches, as well as separate scientific research areas for solve combat tasks. These problems are of importance and preference constantly arise in making decisions on orders complexes in the AME industry, as well as when preparation plans of scientific research and development. Ranking according to the importance of the development of applied, fundamental and exploratory research is significantly when allocation to their implementation of the financial, material and human resources.

4.CONCLUSION

Only in long-term planning, it is possible to implement the end-to-end planning and management of developments of models new technology. Long-term plans serve as the basis for the formation of medium- and short-term plans of scientific research, developments and series production in machine-building and electronic- instrument-making sectors of industries. Long term plans should be based on target predictions, life cycles and cross-cutting plans promising STS and HMS using the system matrices of interrelated "goals-means", providing a systematic approach to the planning of fundamental and applied research, development and production of complex technical and human-machine systems.

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