UDK 623.41+004.451.2
DOI: https://doi.org/1034169/2414-0651.2021.3(31).21-33

V. ZVERSHKHOVSKY, *PhD*
https:orsid.org/0000-0002-5262-5382
(State Enterprise «State Kyiv Design Bureau "LUCH"»)

M. V. ZIRKA, *PhD*
http://orcid.org/0000-0003-2915-3011

V. V. PETUSHKOV, *PhD*
https://orsid.org/0000-0001-6393-1062

O. B. KUCHYNSKA
https://orsid.org/0000-0003-3403-4180
(Central Scientifi Research Institute of Armament and Military Equipment of Armed Forces of Ukraine, Kyiv)

THE PROBLEM OF BLOCK SYNTHESIS OF MISSILE PREPARATION AND START-UP CONTROL SYSTEM FOR MISSILE COMPLEXES

According to the analysis of trends in the use and development of missile weapons, it is shown that in the coming decades such weapons (missile, anti-aircraft missile, anti-ship systems) will remain one of the main units of the armed forces of the advanced countries. At the same time, in the conditions of independent Ukraine there is a need to create its own production of appropriate samples in a "closed cycle". The synthesis of such weapons includes conducting comprehensive research on the principles of construction and operation of their basic elements, namely: substantiation of algorithms for launch equipment, control systems and navigation of missiles. The article deals with an example of a general solution to the problem.

Keywords: *import substitution, missile system, general functional equipment of the launcher, logical system of management and control, missile preparation and start-up control system, algorithm of operation of the missile preparation and start-up control system.*

INTRODUCTION

Combat experience in the Middle East, Afghanistan and eastern Ukraine fully demonstrates the growing importance of high-precision weapons (HFW) in local conflicts, peacekeeping operations and modern warfare in general.

This class of armaments play an important role for Ukraine and its Armed Forces. On the one hand, scientific and production potential for the production of some elements and certain models of such weapons (primarily – missile and artillery weapons), and at the same time abandoning nuclear weapons (sharply increasing the role of strike force implemented on other principles). The HFW is the only and necessary alternative to further supporting the combat readiness of the Armed Forces and the state's defense capabilities. That is, the course for carrying out the corresponding research and development works is perspective for Ukraine and under conditions of positive results, serial production of the above-stated production on a closed cycle.

First of all it concerns missile armament, as in the coming decades such weapons (missile, anti-aircraft missile, anti-ship systems) will remain one of the main units and subdivisions of the armed forces of the advanced countries of the world.

Ukraine is facing an acute problem of import substitution for the production of elements and highly efficient complexes in general (systematic development of missile, anti-aircraft missile, anti-ship complexes were conducted in the Russian Federation).

The development of such weapons in the previous step involves comprehensive research on the principles of construction and operation of the main elements, namely: substantiation of algorithms for launch equipment, primarily preparation and start-up control system, missile control and navigation systems.

Preparation and start-up control system provides centralized control of individual elements of the launcher equipment and coordinates their joint work [1, 5, 6]. The reliability of the preparation and start-up control system decisively affects the overall reliability of the launcher as an element of the missile system. The authors show an example of the general solution of the problem of block synthesis of preparation and start-up control system of missile systems in the article.

The main difficulties of research preparation and start-up control system are:

- breadth and versatility of the problem to be solved;
- preparation and start-up control system – a complex logical system of management and control and consists of many interconnected interacting elements.

SOLVING THE PROBLEM OF BLOCK SYNTHESIS PREPARATION AND START-UP CONTROL SYSTEM OF MISSILE SYSTEMS

Each missile system in terms of its technical performance is a set of equipment of varying degrees of complexity, functionally interconnected and designed to solve the problem before destroying the target. This task is divided into a number of particular tasks. The main ones are:

1. Search, identification and target tracking.
2. Determination of the target coordinates the decision of the meeting objectives.

3. Preparation of the starting system, control and launch missiles.

4. Missile trajectory control.

Each of these particular tasks are solved by a specific system that represents a certain element of the complex's equipment; missile systems are built from functionally the same type of equipment. However, in terms of its design, the functionally equivalent equipment of the complexes differs significantly [2, 4].

Among all the elements of the missile complex, a significant place is given to the launch equipment, which is designed to store the tasks of transporting missiles, deploying an artillery unit or aiming it at a certain point in space with the required degree of accuracy, preparing for a launch, carrying out pre-launch control, launching, as well as two solutions a number of additional pre-launch tasks.

The main element of the launching equipment is the launcher or the starting device. In the general case, the functionally necessary composition of the launcher equipment in accordance with the purpose of each of its elements is conveniently represented by the diagram in Fig. 1.

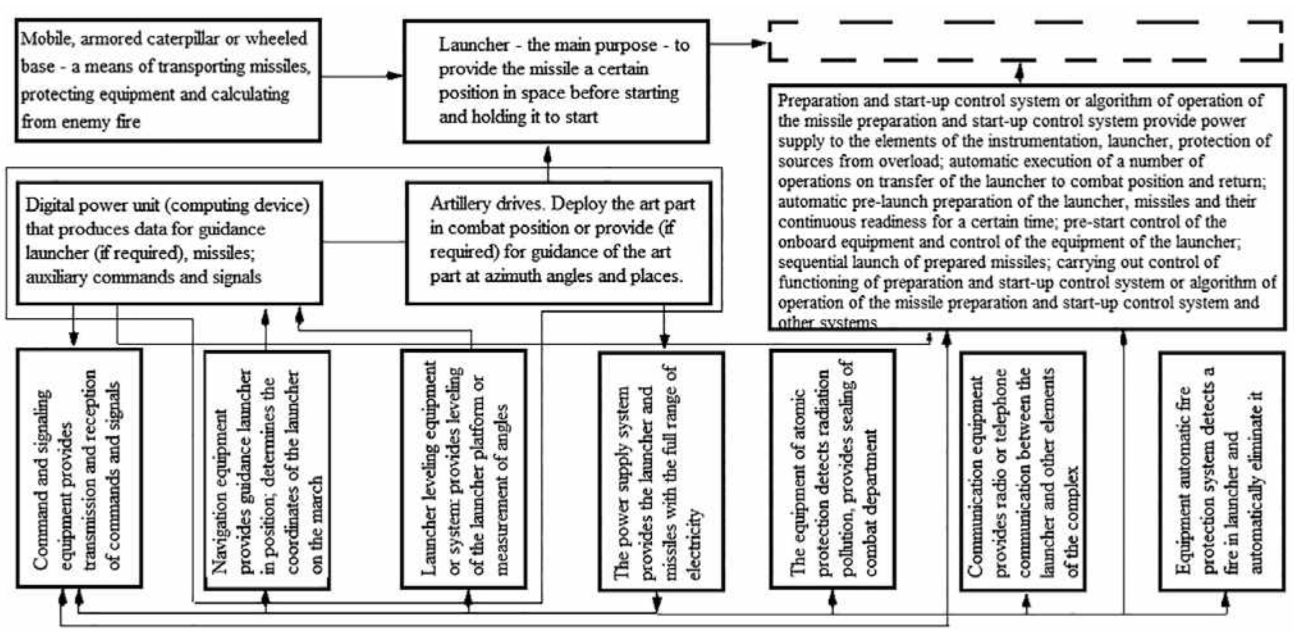

Fig. 1. General diagram of the warehouse of the functional possession of the launcher of a hypothetical missile complex

All launcher equipment is divided into the following several groups:

1. Mechanical part (base and part).

2. Starting control and monitoring systems (starting automation).

3. Power supply.

4. Command and signal communication system (or radar system, if combined with the launcher).

5. Auxiliary systems (anti-nuclear protection, communications, fire-prevention automation, etc.).

The mechanical part should also include the charging device, if the latter is structurally combined with the launcher. Let's take a special look at the second group of launcher equipment (Fig. 2). The starting control and monitoring systems include:

- a system for the deployment or guidance of an artillery unit with a launcher;
- launch control system;
- missile prelaunch control equipment.

The last two types of equipment are combined under the general name preparation and start-up control system, (in some cases – equipment for prelaunch preparation, control and start-up).

The launch control system is designed to provide comprehensive automation of control over the preparation of missiles and launch systems for launch, launching missiles from one point – the central control post.

It includes:

- preparation and launch equipment, which ensures the necessary sequence and interdependence of all preparatory and launch operations with automatic remote control and control of the missile stay in a state of readiness for launch;
- safety control system, which covers all the electric locks, control the execution of safety conditions during prelaunch preparation and start-up [2, 4, 7].

The concept of "system of prelaunch preparation, control and launch equipment" is broader than the concept of "launch control system", since it includes, in addition to the launch control system, equipment for prelaunch control of missiles and in general, equipment for automatic control of the launcher equipment. Automatic control equipment as part of prelaunch preparation, control and launch equipment solves the following tasks:

- monitoring the serviceability of switching circuits and the initial state of on-board systems and systems by the launcher;
- control of the output parameters of individual blocks of on-board equipment and equipment by the launcher according to the "good-bad" or "lower-normal-higher" principle.

The launcher is a system composed of many functionally distinct elements interacting with each other. This interaction is associated with the processing of a certain amount of information about the state and operation of each element in order to ensure that the system performs its functions. With a large amount of information and limited time for its comprehension, processing and decision-making, the operator is not able to satisfactorily cope with this task [3]. Therefore, its implementation kindled on the system preparation and start-up control system, which, however, doesn't eliminate the operator, that is, generally speaking, is also possible, but it unloads, since taking over much of the functionality of information processing.

The preparation and start-up control system can be considered as the centerpiece of the launcher equipment. This system provides centralized control of individual elements of the launcher equipment and coordinates their joint expedient work.

STATE OF THE ISSUE AND POSSIBLE DIRECTION FOR SOLVING THE PROBLEM OF BLOCK SYNTHESIS OF SYSTEMS SUCH AS PREPARATION AND START-UP CONTROL SYSTEM

The system of preparation and start-up control system, in general, is a challenging logic control and monitoring system. The main issues of the analysis and synthesis of this system belong to the field of competence of the theory of relay devices and finite state machines. However, the general theory of systems for preparation and start-up control system can be very fruitfully used idea of hierarchical organization of complex systems [8, 9].

In the theory of relay devices and finite state machines, this idea is reflected in the problem of block synthesis.

Representation of the preparation and start-up control system in the form of a hierarchical structure of interacting automata makes it possible to simplify the task of constructing this complex system and reduce it to constructing the structure of individual simpler automata and establishing connections between them. Machines that are included in the structure of the system preparation and start-up control system belong to a class of synchronous machines and depending on the particular problem to be solved by them may be guns with or without memory storage.

Thus, the previously formulated problem is primarily linked to the problem of the block representation of the structure of the prelaunch preparation, control and start-up equipment and, secondly, both with the general problems of the theory of finite automata and with the specific features of the synthesis of asynchronous automata. At present, the theory of relay devices, which in the interpretation [8] covers all the issues considered in the theory of finite automata and in the theory of neural and logical networks, has achieved significant success in its development and continues to develop rapidly.

The most difficult problem in the theory of relay devices is the problem of synthesis. The synthesis process of a relay device is carried out in several sequential stages. The following is considered as the main steps of synthesis of the relay [2]:

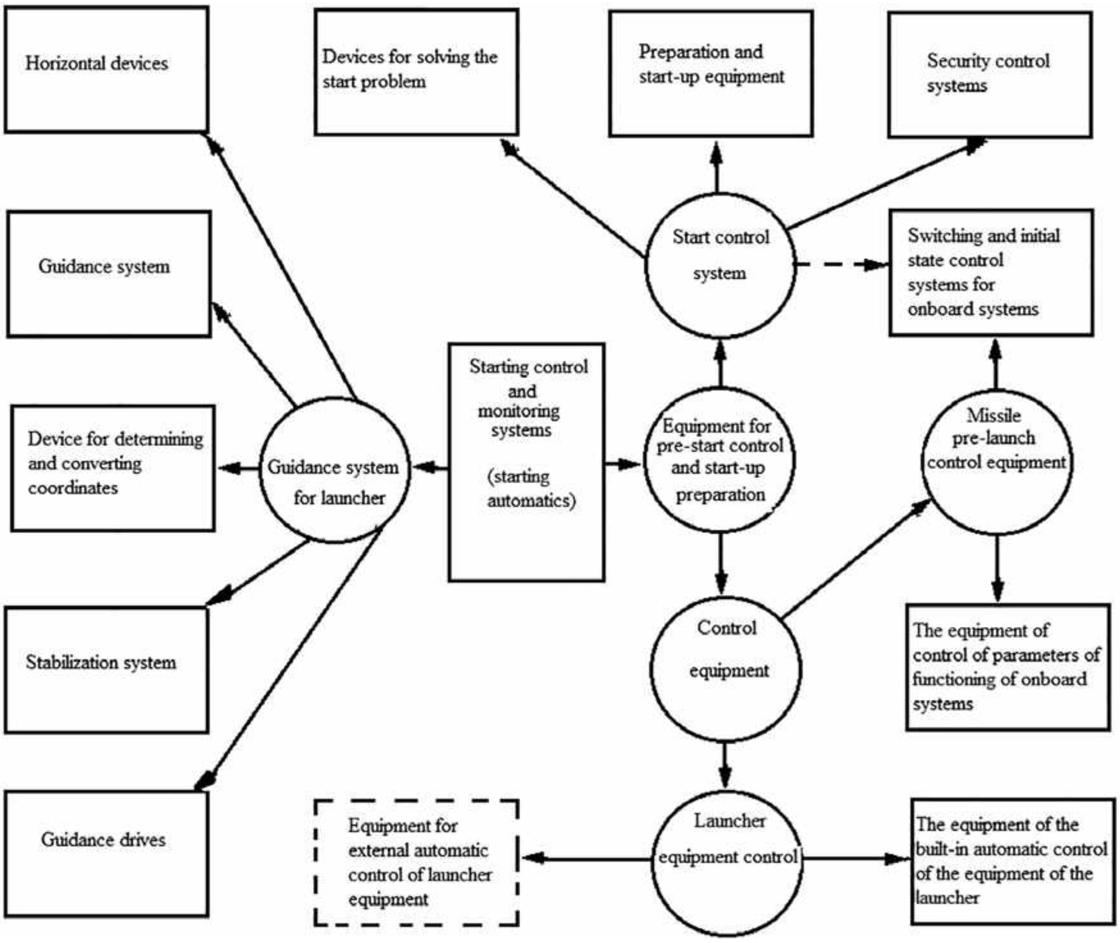

Fig. 2. Start and control system (automatic start)

Step 1. Synthesis of a block.

Step 2. Synthesis abstract.

Step 3. Structural synthesis.

Step 4. Combinational synthesis.

Step 5. Reliable synthesis.

Step 6. Engineering implementation and simulation.

However, the division of the synthesis process into steps is rather arbitrary. The adopted division, by streamlining the synthesis process, makes it possible to facilitate the solution of the synthesis problem for a relay device. Let us consider sequentially the content of the stages of the synthesis of a relay device, the tasks that are solved at each step and methods for their solution.

At the first step of the synthesis, the development and formulation of the operating conditions of the relay device is carried out. If the created relay device is a complex system, then it is divided into separate subsystems or blocks, each of which, in turn, if necessary, can also be considered as a system. In relation to each block, the conditions for its functioning are formulated, that is, all its inputs and outputs are determined and a general relationship is established between the combinations of signals that appear on them. In addition, the conditions are formulated interaction of individual units with each other and with the objects with which the generated relay device. As indicated in [2], at this stage of the synthesis, the main role, unfortunately, is played by intuitive techniques; art and experience of the designer, although recently formal methods have been increasingly used to describe the operating conditions of relay devices. The block construction of the relay device can be provided in connection with the need to obtain various modifications or due to territorial fragmentation individual blocks. At the same time, in the latter case, it may be some displacement of the relay structure of the concept of block representation, with its constructive modular implementation in hardware.

Each block in the structure of the relay device operates according to certain conditions that determine the algorithm for converting this data block. This circumstance makes it necessary to build different formal languages, by which uniquely represented algorithms of relay devices. The language of regular events developed by S.K. Klini and improved by V.M. Glushkov, the language of predicate calculus, the language of inclusion tables, the language of transition tables, as well as a number of other languages [2, 7, 10].

The transition to the use of these languages is carried out already at the Step 2 of synthesis. The result of this stage is the assignment of the relay device by one of the accepted methods, which include transition and output tables, transition tables, transition matrices and inclusion tables [2].

In step abstract synthesis is determined the total number of possible states, which may be the inputs and outputs of the relay, the number of its various internal states established relationship between the changes in internal conditions of the relay and the states of its outputs at various states of its inputs.

In step abstract synthesis depending on the method of the initial representation of the algorithm of the relay is carried out multiple transition from one language to another. Thus, when the recording conditions of work in the language of regular events with the help of a special regular procedure proceeds to the language of transition tables and outputs. With regard to the Huffman method of a similar nature, transitions are carried out directly from the verbal formulation of conditions (the result of the first stage of synthesis) through the partial and primary transition tables to the secondary transition table.

At the first stage of the second stage of synthesis, a transition is made from the formulation of conditions in a natural language to their formulation in any formal language. The choice of a formal language depends on the nature of the task at hand. For example, as indicated in [7, 10], the language of inclusion tables is suitable for specific sequences. When their number is small, the language of transition tables is more general, that is, suitable for both specific sequences and sequences of a general type, but this language has the disadvantage that the initial stage of their construction, which consists in determining the required number of stable states of the internal elements of the relay device for each of the possible states of the inputs, is intuitive. Endless sequences are described in the language of regular events. The language of predicate logic is even broader [7].

The simplest and therefore the most widely used in engineering practice are the language of inclusion tables and the language of jump tables, their relative simplicity expiates their inherent disadvantages.

At one of the stages of the second stage of the synthesis, the problem of minimizing the number of internal states of the relay device is solved. Solution to the problem of minimizing the number of internal states of the relay device terminates the second phase of the synthesis.

The third stage, called the structural synthesis stage, includes a series of sequential steps that provide the canonical equations. The most important task at this stage of the synthesis is the task of placing or encoding states, i.e. the comparison of each state transition table a particular combination of states of internal elements.

If the result of the second synthesis step was to obtain transition tables and outputs the encoded precedes selection of the memory elements (elementary machines) [7]. When performing synthesis by the Huffman method [10], the problem of choosing memory elements does not arise.

The problem of coding the internal states of the relay device is more difficult to solve. This complexity is due to the fact that, on the one hand, coding should provide the most simple structure, and on the other hand, exclude the possibility of critical states. After completing, the transition table coding operations become substantially but in the state table, which usually are cost for synthesizing machines without memory.

Based on these tables are easily obtained by the canonical equations. Either these equations are Boolean functions or potentially pulse shapes that depend on the machine type [7, 10].

The fourth step, step combinational synthesis. At this stage, the question is solved on what elements the automaton will be implemented, its structure is finally selected and its schematic diagram is built. The stage of combinational synthesis is the most developed. The methods of implementing automatic both contact and noncontact elements to [2, 7, 10]. At this stage, an extremely important place is occupied by the questions of minimizing Boolean functions.

Finally, Step 5, which is called the stage of reliable synthesis, involves the transformation and addition of the circuits obtained at the previous stage in order to ensure the reliability of their functioning. In particular, the solution to this problem is achieved by introducing structural redundancy. Much of the work in this area is devoted to the issues of redundancy, which is only a special case of structural redundancy. Allocation of the stage of the reliability synthesis as an independent stage emphasizes the great importance of the problem of the reliability of relay devices [3].

The last stage of the synthesis, called conditional stage engineering implementation involves a calculation of electrical and other elements of the scheme, as well as the carrying out of its simulation to verify functionality. Dividing the synthesis process into stages, facilitating the process of constructing relay devices, can in some cases lead to a complication of their structure, therefore, in order to reduce this drawback, at each of the stages of synthesis, they tend to take into account its influence on the next stages.

Since the Preparation and start-up control system is a system that interacts with a human operator, the state of the problem of its construction is not limited only to questions of structure synthesis, since this structure itself depends on the nature of its connections with operators. This means that, in general terms, one of the sides of the solution of the problem of building a Preparation and start-up control system is to consider the issues of the relationship between human and machine in the system.

As mentioned above, the greatest difficulties are encountered at the very first stage of system design. Especially great difficulties occur when the system is designed for the first time and do not have experience in the creation of this class of systems. The assignment of a system to a particular class is determined by their specific purpose and the nature of the information being processed.

From this point of view the system Preparation and start-up control system of all existing missile systems belong to the same class of systems. The task formulated earlier is to define this specific class of systems, that is, to describe it in the form of some general model that displays the properties inherent in Preparation and start-up control systems. When building a model, obviously, one should proceed from the analysis of existing implementations of the Preparation and start-up control system. Preparation and start-up control systems belongs to the category of information systems and is characterized by an algorithm according to which it processes the incoming information, as well as some structure that implements this algorithm. Therefore, two models that reflect the general algorithm of functioning and the general structure of the organization of the hypothetical system Preparation and start-up control system should represent the class of systems preparation and start-up control system.

Based on these two models, we can try to formulate an algorithm for the class of systems Preparation and start-up control systems that resolves the uncertainty that exists at the first stage of system design. To obtain algorithmic and structural (block) models of Preparation and start-up control systems, the analysis of its various implementations should be carried out, respectively, along the lines of considering the algorithms for the functioning and structural construction of these systems.

The algorithm that describes the functioning of the preparation and start-up control system is a logical algorithm. The most simple and it can be represented graphically in the form of logic operations, each operation denotes an action, and in some cases the sequence of operations to achieve a particular purpose [2, 7, 10]. In general terms, the order of approach to the construction of an algorithm for the functioning of the Preparation and start-up control system can be formulated as the following description:

1. In no particular order and with maximum completeness, list all the tasks that determine the purpose of the system.

2. Considering tasks as operations of a general type, build a logical scheme that determines the sequence and interdependence of the operations listed in item 1.

3. Refine the logical scheme (item 2) and introduce additional operations and connections into it, if necessary.

4. Consider sequentially the tasks (item 1) and, with maximum completeness, list all the operations, the implementation of which makes it possible to solve them.

Operations are formulated at a substantial level in general.

5. Build logic diagrams of operations that ensure the solution of each problem (item 1).

6. Refine logical schemes (item 5) introduce additional operations and connections, if necessary.

7. Each of the operations in logical circuits (item 5) to represent in the form of a logical circuit or an equation of elementary operators, where elementary operators are interpreted, for example, in the sense of the operators proposed by E. Berkeley [2, 7].

The above description provides the order of constructing the algorithm in the direction from general to specific, by gradually deploying operators. The logic diagram of the operators obtained as a result of performing items 1, 2 and 3 can be considered as a generalized algorithm for the functioning of the system.

Logic schemes of operators, obtained when performing items 4, 5, 6, can be considered as subalgorithms of the generalized algorithm. Operators appearing in the generalized algorithm and its subalgorithms can be considered, respectively, as operators of the first and second ranks. Then the operators provided for in item 7 are operators of the third rank.

The subordination of some tasks or operators to others is established naturally intuitively based on the knowledge and experience of the designer. In order to establish the general patterns of building an algorithm for the functioning of the system algorithm of operation of the missile preparation and start-up control system and on the basis of this to construct its algorithmic model, obviously, one should apply to each of the existing implementations of the system algorithm of operation of the missile preparation and start-up control system, consider the general algorithm and subalgorithms included in it, in the sense described above.

Moreover, in order to identify the commonality between the algorithms of different implementations of the algorithm of operation of the missile preparation and start-up control system; there is no need for a detailed consideration of the operators of subalgorithms, since otherwise the general may be obscured by particulars. The transition to the representation of subalgorithms through operators similar or similar to Berkeley operators is more convenient to carry out at a later stage in order to reveal the multiplicity of the representation of operators formulated meaningfully in a general form.

As for the system structure, it is connected with the functioning of the algorithm, but does not coincide with the structure of the algorithm.

In addition, the block construction of a circuit in the general case does not coincide with the block construction of the equipment in which it is implemented.

Under structural organization system circuit is understood a representation of it in the form of a plurality of interconnected blocks. Each block implements a set of operations that belong to one or several subalgorithms, but being covered by a particular unit, the operations determine its structure, as each operation can associate implements some of its analog circuit.

The order of functioning of the unit and the connection between the circuits that implement individual operations in it are determined by the algorithm of the system's functioning.

The Preparation and start-up control system can be viewed as a large hierarchical system. In most cases, you can imagine this system as a three- or four-tiered structure. The lowest element of this structure is composed of logic blocks that control the individual actuators.

Next, a more senior most important element in this hierarchy consists of blocks of logical units, the task of which determine on which algorithm should operate independent of their lower facing blocks. At the top of this hierarchy is the control device that coordinates the sequence of actions of these individual subsystems. Above the entire hierarchical structure is an operator, which can also be considered as a link in the hierarchy of the highest level or rank.

Approaching a specific preparation and start-up control system from the standpoint of the hierarchical principle of construction, it is possible to sequentially distinguish all stages or tiers of complication of its structure in it. Each element belonging to one or another tier of the structure is an asynchronous state machine with a rigid program of actions. Therefore, it is advisable to represent the Preparation and start-up control system in the form of a hierarchy of interacting asynchronous automata. This completely complex hierarchy of automata operates according to the program; determined by a specific algorithm for the functioning of the Preparation and start-up control system.

The value of the model lies in the fact that on its basis the implementation of a specific system can be carried out, in addition, based on the model; it is possible to compare various systems of a given class in terms of their degree of structural complexity, although this assessment is qualitative. Moving from a model to a specific system, it should be borne in mind that, in general, at the first stage of design, the system is multiple in nature, since can be implemented in a variety of options. In this regard, the problem naturally arises of choosing the most rational option. The rationality of the accepted option can be assessed by its effectiveness. In the general case, the efficiency indicator can be considered a functional that depends on many characteristic criteria of the system. However, of all the possible sets of criteria that, for example, are given in [2], the most common are the criteria of reliability and cost. However, in order to get these criteria is necessary to have a scheme already. To get around this obstacle and be able to give preliminary estimates of the adopted option at the earliest stage of the design, it is convenient to associate operators of the third rank with the sets of their circuit analogs.

Each circuit analog of the operator can be assigned a pair of indices $\{P_i / C\}$, of which the first corresponds to the reliability indicator, and the second to the cost indicator.

This allows, by transforming the logical scheme of operators into a logical scheme of reliability [2, 4, 7, 10] and substituting the operators with their reliability indices, to determine the approximate expected reliability of the adopted option, and by summing the cost indices of the operators included in the logical scheme, to determine the cost the option under consideration.

Knowing these two criteria, you can express the effectiveness of the accepted option as their ratio – P_i / C_i. The resulting estimates, although they are indicative, however, allow the choice of an option to be conducted in a more targeted manner and to envisage measures to increase the reliability and reduce the cost of the system at an early stage of design.

Thus, it can be noted that there is an objective need to develop a methodology for constructing systems of the Preparation and start-up control system class, which should allow, in general, to solve the problem of constructing an algorithm for its functioning, finding its block structure and an approximate circuit implementation and assessing its complexity, reliability and cost.

It is appropriate to the following path to solve this problem:

a) analyze system performance algorithms Preparation and start-up control system launcher existing missile systems;

b) on the basis of the analysis algorithm to construct a generalized model of a hypothetical system functioning Preparation and start-up control system, as well as individual subalgorithms included in the generalized algorithm;

c) based on the analysis of the structure of existing implementations of the Preparation and start-up control system, construct a block model of a hypothetical system in the form of a hierarchy of asynchronous automata;

d) to establish a connection between algorithmic and structural models hypothetical system Preparation and start-up control system;

e) transform the schemes of existing implementations of the Preparation and start-up control system (algorithm of operation of the missile preparation and start-up control system) according to the principle of a hierarchical organization. To analyze the construction of machines structures in the hierarchy;

f) based on the analysis performed, build generalized structural models of individual automata in the hierarchical structure of the hypothetical Preparation and start-up control system;

g) establish a connection between the structure of machines and algorithms for their functioning;

h) build a reliable model of the structure of the Preparation and start-up control system. Determine in general terms the reliability and cost of the system;

i) formulate an algorithm for the method of block synthesis of a hypothetical system Preparation and start-up control system, check its applicability on specific examples. Carry out an experimental check on the physical model of the Preparation and start-up control system.

ALGORITHMIC AND STRUCTURAL (BLOCK) MODELS OF SYSTEMS OF THE TYPE ALGORITHM OF OPERATION OF THE MISSILE PREPARATION AND START-UP CONTROL SYSTEM

A generalized hypothetical system functioning algorithm

An analysis of the algorithms for the functioning of the Preparation and start-up control system of a number of existing complexes shows that a certain generalized algorithm can be built. The structure of this algorithm includes typical of the goals and objectives subalgorithms. The diagram in Fig. 3 can represent generalized algorithm of a hypothetical system Preparation and start-up control system. The diagram shows that the general algorithm of the Preparation and start-up control system functioning includes the following subalgorithms:

0 − subalgorithms describing conditions and the order of the power system;

1 − subalgorithm that determines the composition of the set of operations and the order of their execution when bringing the system to its original state.

Subalgorithm 1 is divided into two subalgorithms. One of them 11 is a subalgorithm associated with the performance of tasks to reset those Launcher systems that are common to the onboard systems of all missiles placed on the launcher rails.

The subalgorithm 12 determines the order of operations to reset those items of equipment that are associated with the operation of the onboard equipment of only one missile; 2 − subalgorithms control operation of onboard equipment missiles and launcher equipment.

This subalgorithm is common to all missiles and determines the order of priority for monitoring missile equipment, launchers and its content;

3 − subalgorithms defining the conditions and procedures for bringing on-board systems to a working state. Its advisable to call subalgorithms “Training”;

4 – “Start” subalgorithm. Determines the order of operations to ensure the missile launch;

5 − subalgorithm of post-launch operations;

6 – “Failure” subalgorithm. Determines the sequence of operations that are carried out in the system in case of non-fulfillment of the previous sub-algorithms or missile failure;

7 − subalgorithm of logical connections. Determines the logic of interaction of the above subalgorithms with each other and the conditions for the passage of commands to work out a particular subalgorithm.

This logic varies somewhat from system to system in specific samples. Let us give the logic in relation to the Preparation and start-up control system Launcher of a hypothetical missile complex.

Subalgorithms 7, which determine the functioning of the onboard systems of different missiles of the same Launcher, are interconnected. This connection is manifested, for example, in the exclusion of the simultaneous launch of several missiles, etc. The general algorithm is constructed in such a way that the mandatory indication of the results of the development of each of the subalgorithms is provided [8].

The structure of the operation algorithm of the Preparation and start-up control system, similar to that shown, takes place for any specific system. The differences are manifested in the structure of the subalgorithms. Direct team names and signals in the scheme are not given, so to. These names may be different. The only important thing is that they have the same meaning.

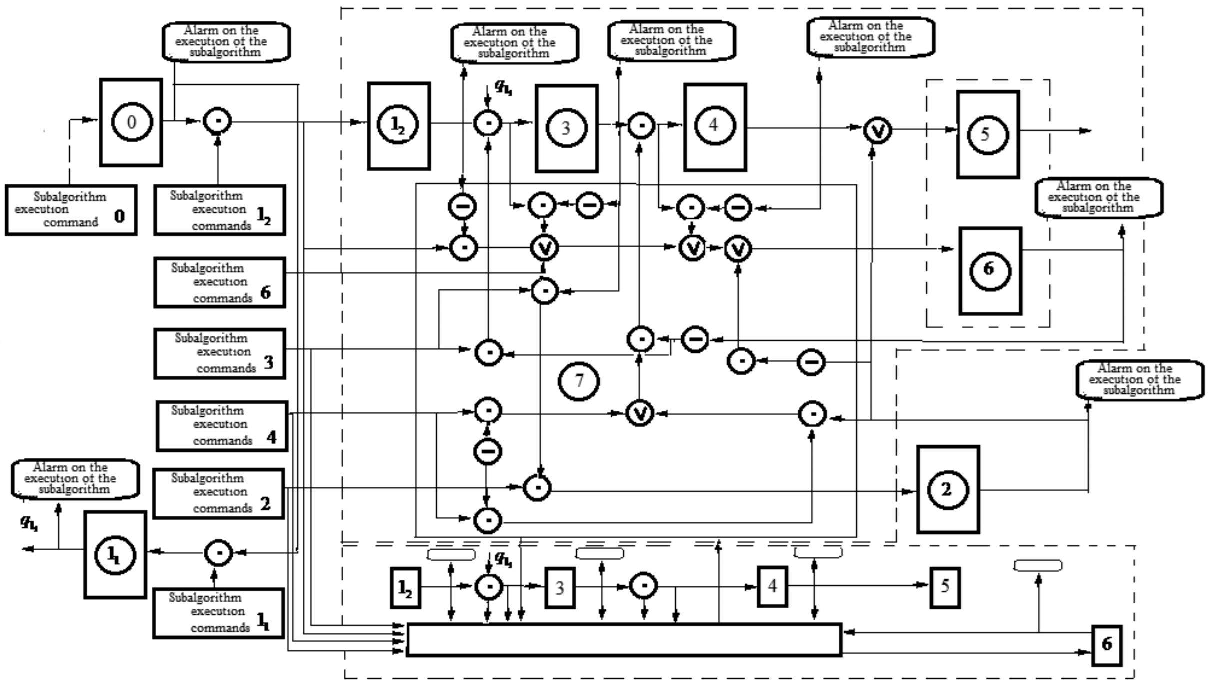

Fig. 3. Generalized algorithm of the hypothetical Preparation and start-up control system

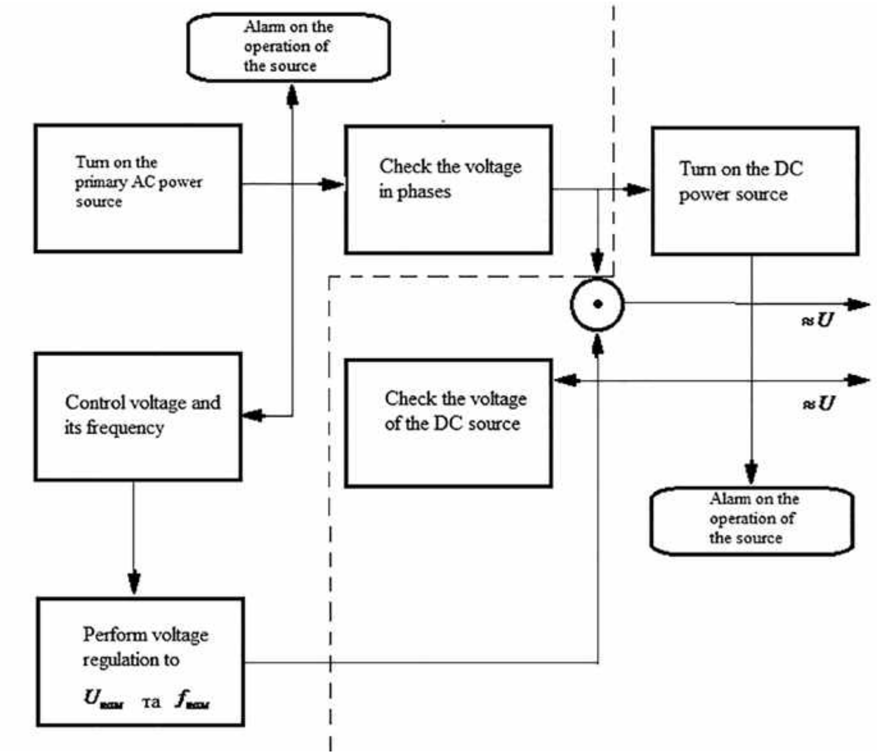

Fig. 4. Subalgorithm “O” − the order of switching on power supplies and control of their parameters

The subalgorithm “O” may be absent in a specific implementation, since power supply and its control are often carried out outside the framework of the Preparation and start-up control system functioning algorithm. However, here it is included in the consideration, since its implementation is a prerequisite for the implementation of operations provided by the rest of the subalgorithms.

Subalgorithms 1_2, 3, 4, 5, 6 and 7 describe the functioning of the hierarchical structure of the automata included in the control system for starts and partially of the systems associated with this structure.

The control subalgorithm “2” determines the order of functioning of a separate, independent structure of machines. Let us represent the subalgorithms in the form of a logical structure of their operations. At the same time, we will strive to ensure that the operations themselves and the logical structure connecting them would be sufficiently general.

Let us consider as an example the content of some subalgorithms that are part of the generalized algorithm for the operation of the Preparation and start-up control system.

Subalgorithm “0” is associated with the tasks of supplying power to the system. The power supply of the equipment of launchers, including the Preparation and start-up control system, is carried out from both AC and DC sources. As sources of alternating current on mobile launchers, alternators are used that generate voltage with a frequency of 400 Hz. Sometimes two types of alternating voltage are used with a frequency of 50 Hz and 400 Hz. The primary DC power semiconductor rectifiers are used either or batteries and generators base. The main content of subalgorithms “O” defines the procedure for switching power supplies and control their parameters (voltage, frequency, etc.). The diagram in Fig. 4 can represent this subalgorithm. The operation of the primary switching an AC source is connected with the necessity of startup of the prime mover. The device by the operator can carry out the voltage control in the phases, but a special circuit, which, in the absence of one of the phases, removes the signaling about the operation of the source, can also carry it out. Voltage regulation is carried out in accordance with the readings of the monitoring device by influencing the set point, which is an element of the automatic voltage regulator circuit. Adjusting the AC voltage level automatically maintains the rated value of the DC source if the latter is a rectifier. In a number of rocketry models, only direct current power systems are used. These systems include base machine DC generators and batteries. For samples with a similar organization of the power supply system, the “O” subalgorithm is represented only by the right side of the diagram in Fig. 4, which is complemented by the introduction of the voltage control operation. In Fig. 3, the signaling, which is the result of working out the “O” subalgorithm, includes signaling about the operation of sources and readings of control devices, which contributes to the signaling considered in Fig. 4.

The main content of the subalgorithm “1” determines the bringing of the elements of the Preparation and start-up control system to the initial state, from which the operation of this system begins. This subalgorithm, as shown in Fig. 3, is divided into two parts, which, however, are closely related to each other. Development of subalgorithm “1” is triggered by supplying supply voltages to the Preparation and start-up control system equipment. The issuance of these stresses is a command for practicing subalgorithms “”. In addition to these commands, a series of additional commands is issued to test the subalgorithm “”. The content of the latter, as well as the content of the subalgorithm “” is determined, as a

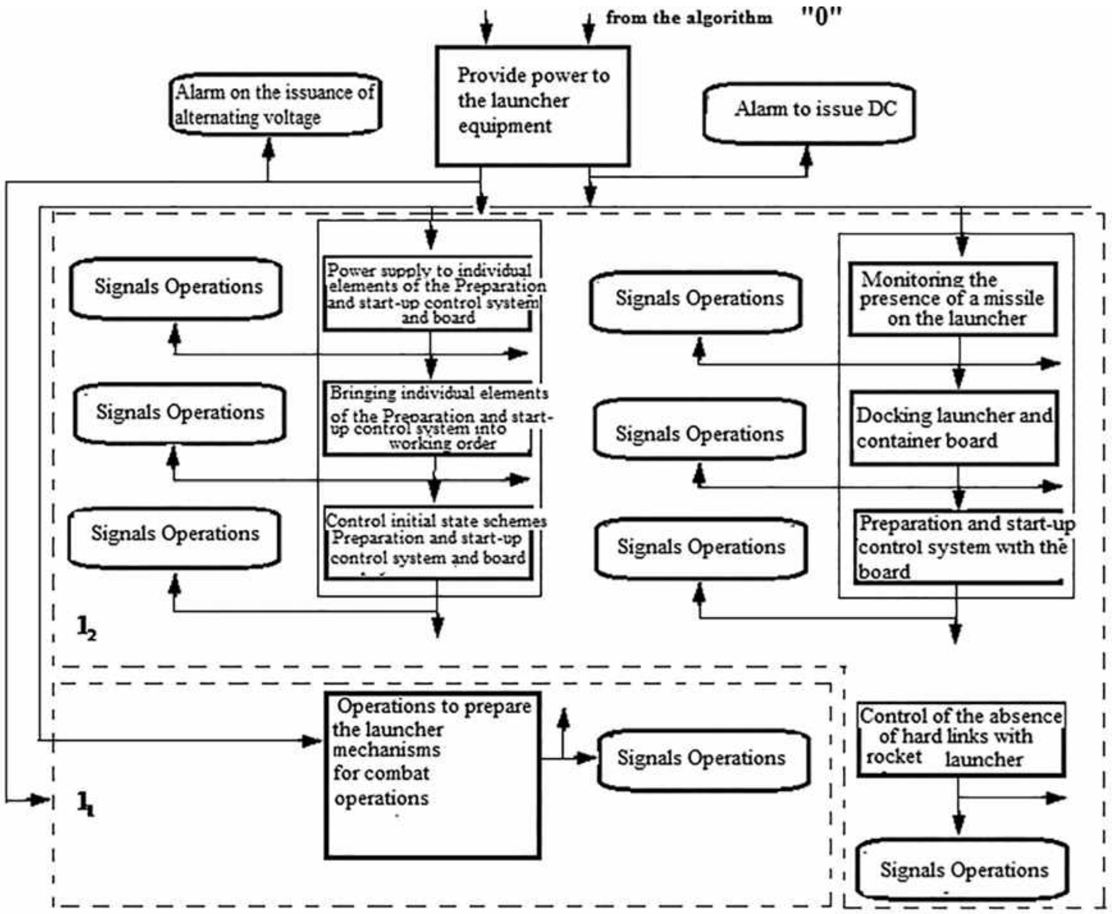

Fig. 5. Subalgorithms "1" – actuation elements Preparation and start-up control system of the system to its original state (launcher)

rule, by the level of automation of some operations to bring the Launcher into a combat state. The diagram in Fig. 5 can represent subalgorithm "1" in general form.

An attempt to specify reduced subalgorithms makes it necessary to refer to specific examples of missiles and launchers. The content of the subalgorithm "L_1" is defined rather general, since it can be very diverse, depending on the design of the Launcher [8].

However, some general operations can be distinguished here. Such operations are, for example, control of the interlocks of the position of the elements of the mechanical part of the Launcher (the swinging and rotating parts are unlocked, additional supports are removed, hatches are closed, etc.), power is supplied to the Launcher equipment. But these common tasks are solved in specific implementations in different ways. Let the subalgorithm "1" for a hypothetical Launcher include operations for balancing the swinging part, preliminary switching on of the guidance drives, etc., which is not the case for other samples. The execution of each operation is accompanied by the issuance of a corresponding alarm, if the operation is associated with the operation of the independent mechanism of the Launcher. Only two groups of operations are shown in the "l_2" subalgorithm, and the operations last in the chain forming the group are the most common.

Operations that precede them may in some cases be absent or very complex. Monitoring the presence of missiles at the Launcher is often identified with monitoring the electrical connection of the aircraft and the Preparation and start-up control system scheme. It is rather difficult to represent subalgorithm "1" in general form. Common to all implementations of the subalgorithm is only the result of its execution, which determines the initial state of the system, and even then, only in the sense that its work begins from this state and the ways to achieve this state can be varied.

Thus, to construct subalgorithm "1", it is necessary to know the specific design of the missile, container and launcher and to have a vivid description of the initial state of their systems. This description should determine in what position the elements of the equipment of the launcher, container and missile should be in the period preceding the beginning of the transfer of the equipment of the board into working condition.

In general terms, this state can be described as follows:

- the missile in the container must be installed on the artillery unit, docked with the Launcher using a connector;
- the board scheme must have an electrical connection with the Preparation and start-up control system scheme;
- the rocket should have no mechanical connection to the launcher, which would exclude the possibility of its free start (Remove the fasteners that provide a rigid connection with the container and rocket launchers);
- for some missile systems, the rotating and swinging part of the Launcher has the ability to move freely within predetermined limits (the marching mounts and auxiliary supports have been removed);

- the hatches are closed, the safety of the calculation is ensured;
- on the Launcher, the power supplies are on;
- power is supplied to the Launcher equipment, including the Preparation and start-up control system; the equipment of the Launcher is in working condition or in a condition close to working;
- some of the elements of the Preparation and start-up control system circuit are in working condition (individual relays have triggered, separate secondary sources are working, etc.);
- voltage is applied to individual elements of the board equipment (heating or semi-heating of cathodes in a number of blocks, heating of ampoule batteries, warhead, etc.);
- individual elements of on-board equipment are reset (for example, an on-board power switch) and the initial position of a number of elements is monitored (locking of gyroscopic devices, the position of the on-board power switch, in some cases the position of the elements of the safety-actuating mechanism).

The above description clarifies the content of the operations indicated in Fig. 5. So, if it is envisaged to supply power to individual elements of the board, then first the position of the elements of the safety-actuating mechanism (missile safety) is monitored, then the position of the on-board power switch, and only after that certain types of power are supplied. The signaling about the initial state of the entire system can be quite diverse, since it is associated with the operation of a number of individual subsystems of the Preparation and start-up control system.

Let's consider subalgorithm "3". This is a subalgorithm, the implementation of which ensures the preparation of the rocket for launch. The content of the subalgorithm in relation to specific samples of systems is different. However, these differences are manifested mainly in the ways of its implementation. The main result of working out the subalgorithm "3" in all cases is the same and is characterized by the state of the onboard equipment and systems of the Launcher, which in general can be described in the following form:

- tested missiles safety (safety-executive mechanism) and the condition of the elements of pyrotechnics;
- on-board equipment systems are powered from a ground source;
- avionics system reached the mode and ready for action (warmed up elements of electronics, gyroscopes reached the rated speed);
- onboard power supplies are turned off;
- the launcher is powered by sources supplying the onboard equipment, the voltage output by these sources is monitored (presence of phases, voltage level, etc.);
- the launch safety is ensured (hatches are closed, the prohibition zone is monitored, etc.);
- prepared chains for launching one of the missiles, launching for all other missiles is prohibited;
- the time spent by the onboard equipment in working condition is monitored (monitoring of the thermal conditions of the board).

This description defines the preparation subalgorithm, which can be represented by the diagram in Fig. 6. Contents shown in fig. 6, operations in individual cases can be enlarged, recessed, but their main meaning is not changed.

The task of monitoring the safety of an aircraft can and generally be limited only to monitoring the safety-executive mechanism and, as was shown earlier, in a number of cases

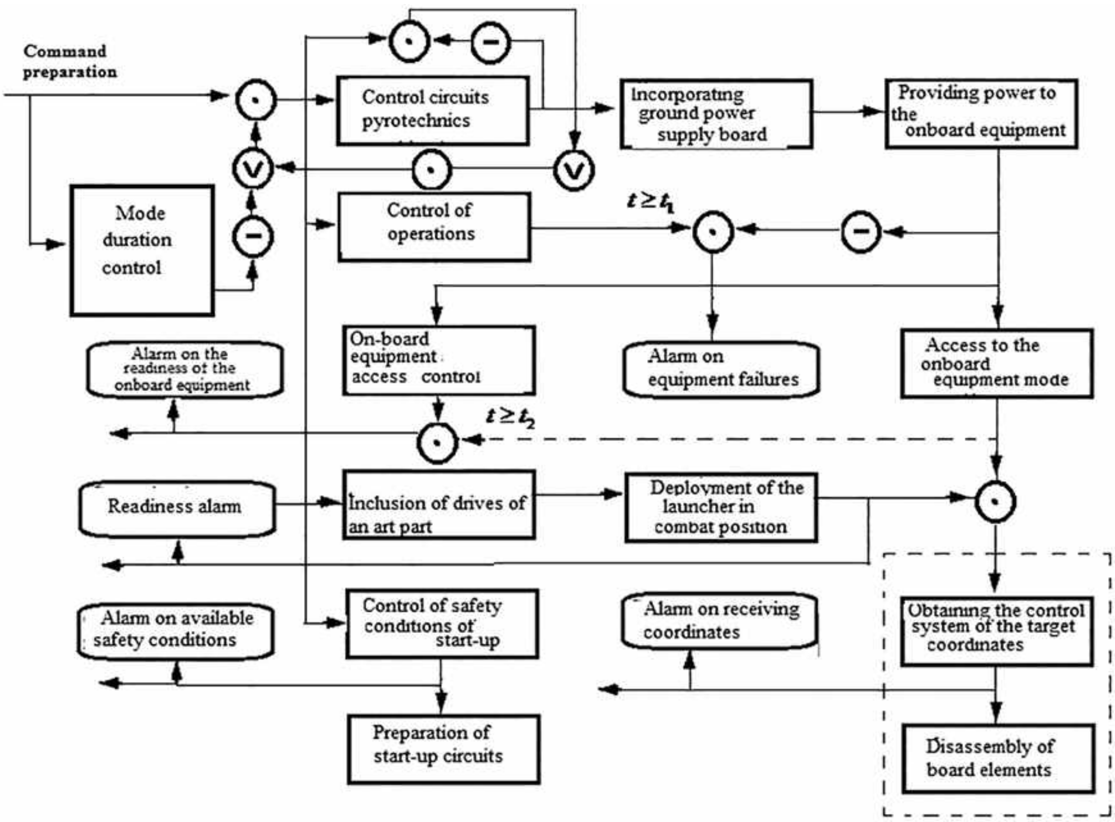

Fig. 6. Preparation subalgorithm (CS – control system)

is associated with the “1” subalgorithm. The locking control can be transformed into issuing the “Lock” command.

The signal for working out the given subalgorithm is identified with one or more signals that appear when working out individual operations. If the subalgorithm-processing signal must be the only one, then all signals associated with the processing of individual operations must be combined by a logical link “AND”.

The given subalgorithm is constructed in such a way that it controls the execution of individual operations or a group of operations. The existing control operations samples carried out by controlling the duration of their execution. In the normal functioning of the system, the duration of operations should not exceed a certain value. If, however, it will be greater than this value, this fact is regarded as a fault. In this case, the signal is given to stop working and the system to the initial state.

The operation of preparing the launch circuits provides for the prohibition of the simultaneous launch of several missiles and the generalization of all signaling about the performance of operations that provide conditions for the launch.

The drive is an independent system of the launcher and the operations associated with its operation, although they are included in the subalgorithm, but the operation of the Preparation and start-up control system is associated only with the signaling issued at the same time [2, 8].

One of the main subalgorithms of the Preparation and start-up control system are: start-up subalgorithm “4”. If you compare the contents of this subalgorithms for different systems, it turns out that they are very close. The main content of this subalgorithm is determined by operations to bring the onboard sources into working condition, control their entry into the mode, switch to onboard power supply and launch. For the general case, the subalgorithm “4” can be represented by the diagram in Fig. 7.

In fig. 7, solid lines show the main operations and connections accompanying the execution of the start-up sub-algorithm. Operations and links indicated by dotted lines correspond to specific implementations of this subalgorithm.

The subalgorithms of post-launch operation “5” and refusal “6” are alternative in meaning, but not in content. The first determines the program of actions in the event of a missile descent, and the second in case of a non-descent. Subalgorithm “6” in many respects repeats subalgorithm “5”, but it is performed forcibly. The operations provided by these subalgorithms either coincide or are closely related to each other, so one could consider these subalgorithms as a single subalgorithm, but it is more logical to consider them as independent subalgorithms.

The argument for independent consideration of the subalgorithm “6” is that this subalgorithm controls not only the development of the start subalgorithm (4), but also the

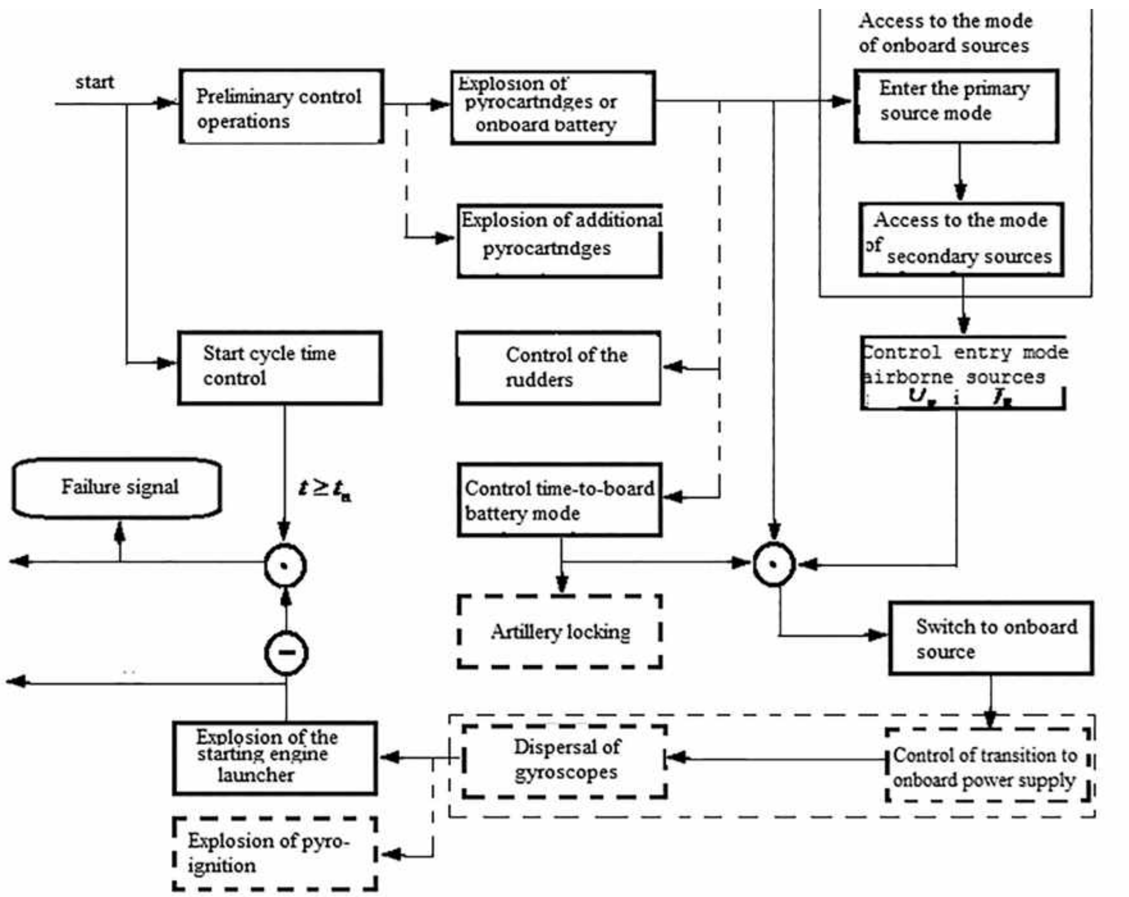

Fig. 7. Subalgorithm of start-up (PPA − powder pressure accumulator; PC − pyrocartridge; SA − safety-actuator; e.g. − for example, BINS − onboard inertial navigation system)

development of all previous subalgorithms and a number of operations included in them, the failure of which can lead to an emergency.

The following operations are common to these subalgorithms:

- the cancellation of all commands that were issued to the launch control system scheme, which provides the preparation and launch of the missile in question;
- launch control circuit system associated with the considered a missile contained in the initial state;
- the ban on launching the next missile is canceled;
- ground sources of onboard power supply for the given missile are turned off;
- if the launcher has only one missile, or if the missile in question remained the last on the launcher, and all the others started or failed, then the launcher is set to the loading angles.

As one of the special operations in the “6” subalgorithm, it is often envisaged to generate a command on board to disconnect onboard sources in the event of a missile failure, as well as some additional operations to ensure the safety of the missile. The subalgorithm “7” in its content cannot be clearly defined in the general case. According to its meaning, it determines the logic of connections between individual subalgorithms, the sequence of commands passing depending on the results of the subalgorithms and individual operations in them.

Each of the subalgorithms, when working out the operations included in them, provides for the issuance of a number of signals. The problem of logical processing of these signals and commands coming from the operator is solved by subalgorithm “7”. The result is the issuance of commands for working out subalgorithms and signals to the operator. The structure of subalgorithm “7” is individual for each specific case.

Subalgorithms control “2” in the general structure of the algorithm operation Preparation and start-up control system occupies a special place. The control equipment forms some functionally independent system in the Preparation and start-up control system. This equipment is used to control the quality and reliability of both aircraft systems and equipment launcher.

The development of subalgorithms that determine the operation of the launch control system also provides for a number of control operations. However, these control operations do not cover all missile equipment. These operations control only those systems that are directly related to the launch of the rocket. This includes control operations for pyrotechnics, safety-actuating mechanism, locked position of gyroscopic elements, initial state of individual aircraft units, entering the mode of the onboard power supply system, etc.

The content of the control subalgorithm “2” is associated with the control of the operation of the radio fuse, the autopilot, the homing head, as well as the operation of the control over the functioning of the Launcher equipment. As a result, full control of the onboard equipment and the main systems of the Launcher is provided. Moreover, the peculiarity of this type of control is that the equipment is checked in dynamics, i.e. control equipment in the course of its work. The tasks solved by the control equipment are very extensive. Due to the variety of implementations of controlled equipment, the structure of the subalgorithm “2” should be determined for each specific case individually [2, 4, 8].

CONCLUSIONS

Thus, the block synthesis algorithm determines the content and sequence of solving the synthesis problem for systems such as preparation and start-up control system of the Launcher of the missile complex at the stage of block synthesis. Result of its application, the block structure of this system in the form of hierarchy of automatic machines of different ranks can be received, algorithms of functioning of separate automatic machines and communication between them are defined.

The applicability of this algorithm to the construction of preparation and start-up control system for this task systems supported phase synthesis block in constructing the system preparation and start-up control system for some hypothetical missile complex.

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Звершховський І.В., Зірка М.В., Петушков В.В., Кучинська О.Б.

ЗАДАЧА БЛОЧНОГО СИНТЕЗУ СИСТЕМ УПРАВЛІННЯ ПІДГОТОВКОЮ ТА ПУСКОМ РАКЕТ РАКЕТНИХ КОМПЛЕКСІВ

За результатами аналізу тенденцій з застосування та розвитку ракетного озброєння показано, що в найближчі десятиліття така зброя (ракетні, зенітно-ракетні, протикорабельні комплекси) залишиться однією з основних у частинах та підрозділах збройних сил передових країн світу. Разом з тим, в умовах незалежної України з'являється необхідність у створенні власного виробництва відповідних зразків в режимі «замкненого циклу». Синтез такого озброєння включає проведення комплексних наукових досліджень з питань принципів побудови й функціонування їх основних елементів, а саме: обґрунтування алгоритмів роботи пускового обладнання, систем управління та навігації саме ракет. В статті показаний приклад загального вирішення задачі блочного синтезу систем управління підготовкою і пуском (СУПП) ракетних комплексів. Ця система займає значне місце у складі ПУ та комплексу в цілому і призначена для вирішення задач розгортання артилерійської частини, підготовки до старту, здійснення передстартового контролю й пуску, а також для вирішення додаткових передстартових задач. СУПП забезпечує централізоване управління окремими елементами обладнання ПУ та координує їх спільну роботу. Надійність роботи СУПП рішучим чином впливає на загальну надійність ПУ як елемента ракетного комплексу.

Ключові слова: *імпортозаміщення, ракетний комплекс, загальне функціональне обладнання пускової установки, логічна система управління і контролю, система управління підготовкою і пуском ракет(СУПП), алгоритм функціонування СУПП.*

Відомості про авторів:
Звершховський Ігор Всеволодович
кандидат технічних наук
начальник комплексного конструкторського відділу Державного підприємства «Державне Київське конструкторське бюро "Луч"»,
м. Київ, Україна
https://orcid.org/0000-0002-5262-5382

Information about the authors:
Zvershkhovskyi Igor
Candidate of Technical Sciences
Chief of the complex design-engineering department of the State Enterprise «State Kyiv Design Bureau "Luch"»,
Kyiv, Ukraine
https://orcid.org/0000-0002-5262-5382

Зірка Марія Василівна
кандидат технічних наук,
молодший науковий співробітник науково-дослідного відділу Центрального науково-дослідного інституту озброєння та військової техніки Збройних Сил України
м. Київ, Україна
http://orcid.orl/0000-0003-2915-3011

Zirka Mariya
PhD, Researcher of Research Department of the Central Scientific Research Institute of Armament and Military Equipment of Armed Forces of Ukraine, Kyiv, Ukraine
http://orcid.orl/0000-0003-2915-3011

Петушков Володимир Валерійович
кандидат технічних наук
начальник науково-дослідного відділу розвитку ракетного озброєння та військової техніки тактичного і оперативно-тактичного призначення науково-дослідного управління розвитку озброєння та військової техніки Сухопутних військ Центрального науково-дослідного інституту озброєння та військової техніки Збройних Сил України,
м. Київ, Україна
https://orcid.org/0000-0001-6393-1062
e-mail: developervia@i.ua

Кучинська Оксана Борисівна
начальник науково-інформаційного відділу Центрального науково-дослідного інституту озброєння та військової техніки Збройних Сил України,
м. Київ, Україна
https://orcid.org/0000-0003-3403-4180
e-mail: 10fa@ukr.net

Petushkov Volodymyr
Candidate of Technical Sciences
Head of the Research Department for the Development of Missile Weapons and Military Equipment of Tactical and Operational-Tactical Purpose of the Research Department for the Development of Weapons and Military Equipment of the Land Forces of Central Scientific Research Institute of Armament and Military Equipment of the Armed Forces of Ukraine,
Kyiv, Ukraine
https://orcid.org/0000-0001-6393-1062
e-mail: developervia@i.ua

Kuchynska Oksana
Chief of scientific-information department of Central Scientific Research Institute of Armament and Military Equipment of Armed Forces of Ukraine,
Kyiv, Ukraine
https://orcid.org/0000-0003-3403-4180
e-mail:10fa@ukr.net

The article was received by the editorial board on 20.07.2021.