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DESIGN METHOD OF SURFACE-TO-AIR MISSILES USING THE OBJECT-ORIENTED APPROACH AND ELECTRONIC LAUNCH TECHNOLOGY

The article discusses the system-conceptual aspects of the design of surface-to-air missiles (SAM). A spiral object-oriented design model for SAM is proposed, which allows increasing the design efficiency with a reduced volume of pilot flight tests. The formation of classes, objects and structures has been completed, they are the formalized mechanisms for the synthesis of SAM, using the theoretical foundations of the object-oriented design methodology, combines the process of object decomposition and the presentation of the logical, physical, static and dynamic models of the designed system.The proposals on the development of the method of "electronic launches" as technologies, which unites, within the framework of common approaches, questions of testing and simulation modeling of SAM at all stages of designing.

Keywords: *object-oriented synthesis, guidance loop of SAM, SAM design, anti-aircraft missile system, classes and objects of the model, the method of "electronic launches".*

Introduction

Problem statement and literature analysis. Experience in the design of high-precision weapons systems in Ukraine has shown that the classical block-hierarchical design paradigm and cascade (waterfall) model of the life cycle no longer provides sufficient efficiency to the design process. And this is due to the fact that the design of modern high-precision weapons systems based on network-centric technologies requires new approaches to the methodology for their creation.

When considering the methodology of creating modern weapons, first of all, attention should be paid to the work [1–5]. The problems of substantiation of requirements for modern weapons and military equipment are discussed in the works [6–9]. Particular attention should be paid to the works [9–13], that deal with the design of surface-to-air missiles, the creation of models for the guidance loop, and a computational experiment. The work [14] can be recommended as an example of the construction of modern model-oriented platforms for the development of complex radio engineering systems. The problems of object-oriented design are covered in [15].

The purpose of the article is to consider the use of a spiral object-oriented design model of SAM, which improves design efficiency with a reduced amount of flight control tests and simulation modeling – "electronic launch" as part of a unified methodology for SAM designing and testing.

Statement of basic materials

Formally, the works on the creation of complex military and technical systems can be divided into design, construction, manufacture and testing, which are divided into a number of stages [1–5].

The logic of the design process of SAM is built on the cascade (waterfall) model [5]. The existing design approach considers a precise formulation of the initial requirements for SAM. Partial requirements specifications for the creation of rocket equipment should be coordinated before the start of work. Coordination of partial requirements specifications with the executor requires the performance of relevant researches, which can not be funded by the customer. The final approval of the partial requirements specifications is carried out in the course of the project. All this leads to the fact that for the customer there is a high level of risk and unreliability of investments. The results of the project are available to the customer only at the end of the work (stage), which leads to significant difficulties in management of the design process of SAM and complicates the parallel work on the project.

The experience of design work on the program for the creation of future-technology SAM showed that, the existing sequence of design stages allows the implementation of the spiral (evolutionary) model of the missile creation.

The spiral model of design and test of SAM is shown in Fig. 1.

With such a design model, the conformity assessment of the characteristics of the designed SAM to the specified requirements is carried out not at the end of the stage, but continuously during the execution of the design work. The customer has the ability to plan the partial requirements specifications at the next stage and carry out its scientific processing and coordination with the executor.

Thus, the process of design and test becomes continuous, and its division into separate stages is related only to organizational and financial issues.

Very important for the purposes of our consideration is the remark by B.A. Demidov [3] that: *a product* *of a design is a model of an object that does not really exist at the time of design.*

At the starting of the design, SAM is presented as a concept with a high degree of abstraction, which has a number of properties that make it possible to distinguish SAM from other missiles (for example, aviation, ballistic, etc.).

Surface-to-air missiles designing is reduced to the sequential solution of a group of tasks that relate either to synthesis problems or to analysis problems.

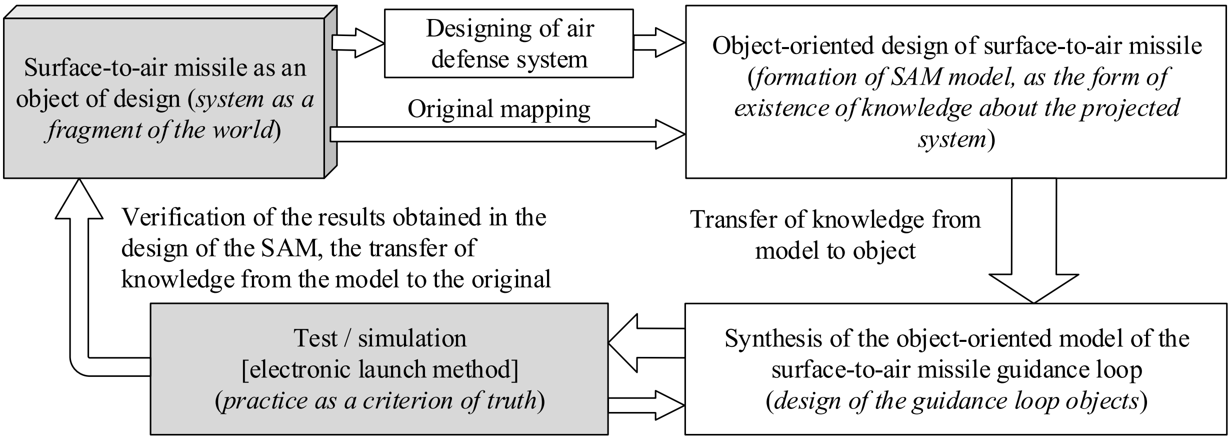


Fig. 1. Spiral model of surface-to-air missile design and testing

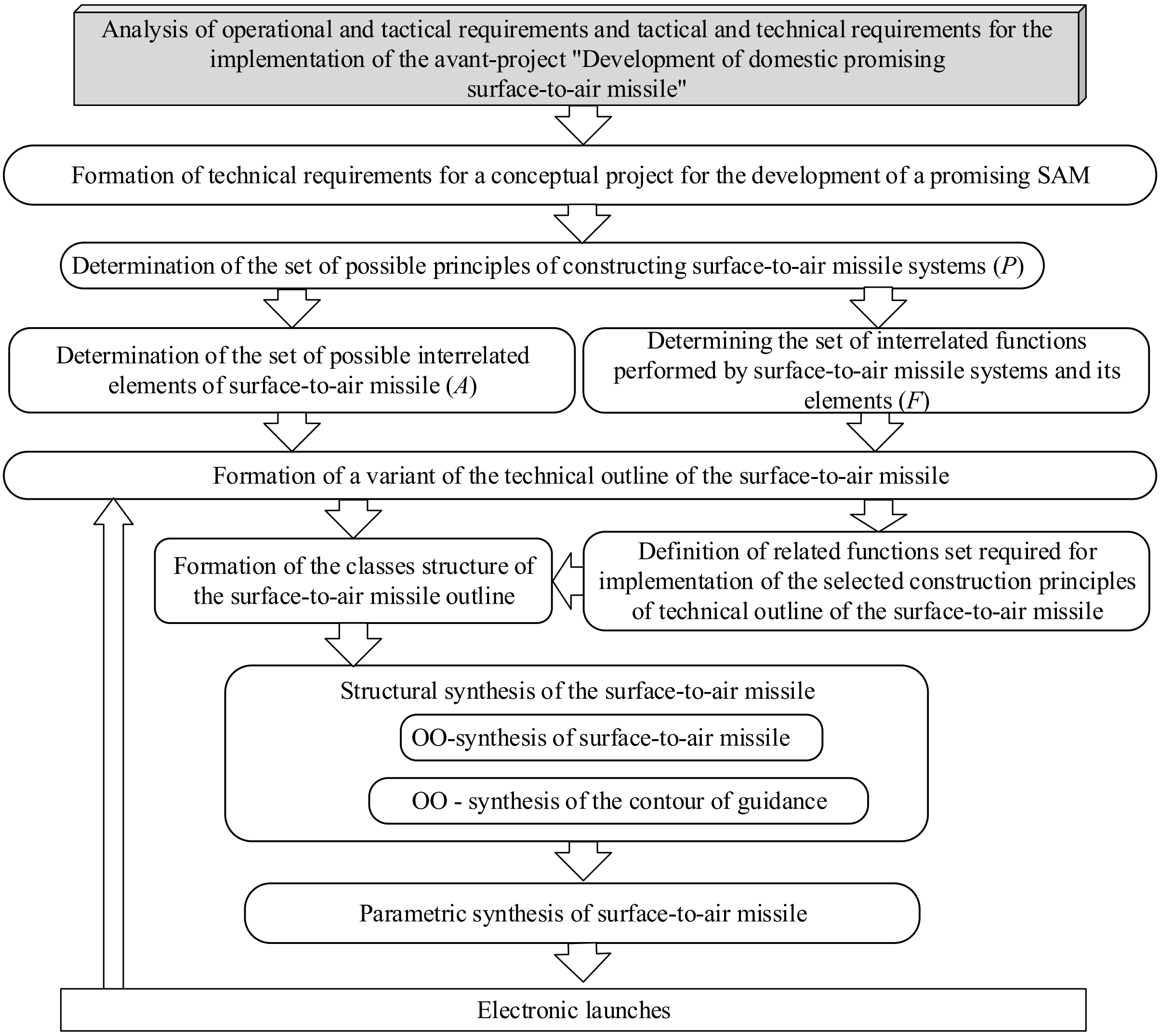


Fig. 2. The general structural scheme of the object-oriented design method of surface-to-air missile

Fig. 1 shows the general structural diagram of the object-oriented design of SAM.

The synthesis of SAM is the process of generating the functions, structure and parameters of SAM according to the requirements set by the operational and technical requirements (OTR) and tactical and technical requirements (TTR), achieving the specified performance characteristics, required and sufficient to perform the assignment tasks.

The analysis of SAM is a study of the features of some variant of the construction SAM.

In the formalized problem of the synthesis of SAM as a complex military and technical system are highlighted [5]:

P – set of possible principles of design of air defense system (ADS);

F – set of interrelated functions realized by ADS and its elements;

A – set of possible interrelated components of surface-to-air missiles.

Each set of Π principles corresponds to a set of $F(\Pi)$ functions, from which it is necessary to choose $f \in F(\Pi)$ subset sufficient to implement the specified construction principles.

The elements of the F set are mapped to the elements of the A set. This image is characterized by some operator

$$H\colon A = H(F).$$

In the general case, the task of synthesis of SAM structure is to determine [5]:

– sets of principles of design

$$\Pi \in P; \tag{1}$$

– sets of functions performed by ADS

$$(f \in F(\Pi)); \tag{2}$$

– sets of elements that can implement the chosen principles and carry out functions

$$(a \in A) \tag{3}$$

in determining the optimal projection of the elements of the set of performed functions on the set of interrelated elements

$$[a \in A] = H[f \in F(\Pi)]. \tag{4}$$

The combination of all functions of the system and its components form the functional structure of the system, which is built on a hierarchical basis. For complex systems consisting of a large number of elements, the functional structures are rather cumbersome and difficult to analyze. Thus, condition (2) of synthesis by standard methods is difficult to analyze. The same situation takes place with elements of the structure (4).

One of the approaches invented by mankind to overcome complexity is an abstraction. We introduce the concept of the classes structure and the objects structure that together form the system architecture. Moreover, we consider the class as a rather abstract knowledge system (1–4) about SAM, the name of which coincides with the class name. Classes form a structural hierarchy of the type "to be part", objects of type structure "is a" [15]. Further, the functions described in the class can be implemented using a variety of different structures. Objects are generated by classes and represent the implementation of any variant of the structure that provides the execution of the specified functions.

Actually, the design process is a process of abstract thinking. New obtained knowledge about the missile requires confirmation by practice.

The process of transferring abstract knowledge to a specific object is a construction process (Fig. 1). There is no difference if a concrete physical object or simulating model is constructed.

The method of synthesis of the object-oriented model of SAM guidance loop involves the stages of research shown in Fig. 3.

Air defense system is a large system that is not observed simultaneously from the perspective of one observer, for which there is a significant spatial factor, the number of subsystems of which is very large, and the composition is heterogeneous.

The system decomposition of the design task of SAM leads to the fact that in composition of SAM there are separate units of armament and military equipment [5]:

$$A = \{A_1, A_2, \ldots, A_n\}. \tag{5}$$

For each unit of equipment it is possible to determine the set of its system functions

$$FS(A_i) = \{FS_{i1}, FS_{i2}, \ldots, FS_{im}\}. \tag{6}$$

For SAM it is possible to determine the set of XM input impacts

$$XM = \{x_1, x_2, \ldots, x_l\}. \tag{7}$$

The interconnection between the system functions of the armament and military equipment sample from the composition of SAM and the set of input impacts of the XM missile can be represented as a matrix of binary relations

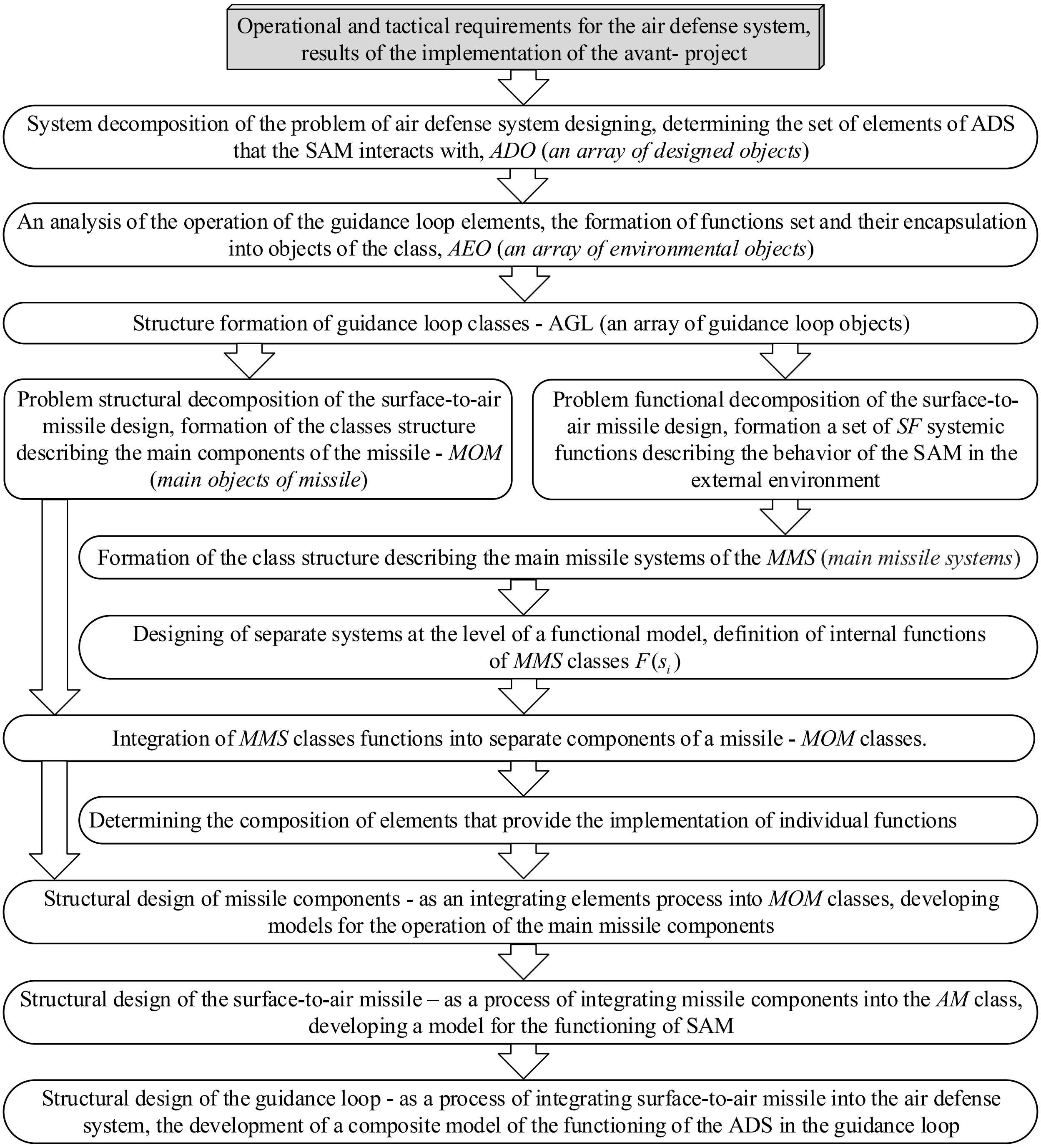
$$\left\| \mathrm{c}_{\mathrm{j(k)}} \right\| = [FS(A_i) \times X_m] =$$

$$= \begin{array}{cc} \begin{array}{ccccc} FS_{i1} & & FS_{ik} & & FS_{im} \end{array} & \\ \begin{bmatrix} c_{1(1)} & \cdots & c_{1(k)} & \cdots & c_{1(m)} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ c_{j(1)} & \cdots & c_{j(k)} & \cdots & c_{j(m)} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ c_{m(1)} & \cdots & c_{m(k)} & \cdots & c_{m(l)} \end{bmatrix} & \begin{array}{c} x_1 \\ \\ x_j \\ \\ x_l \end{array} \end{array}, \tag{8}$$

$$c_{\mathrm{j(k)}} = \begin{cases} 1, \left\langle FS_{ik}, x_j \right\rangle \in R^s; \\ 0, \left\langle FS_{ik}, x_j \right\rangle \notin R^s. \end{cases}$$

This armament and military equipment sample enters the guidance loop when $\exists \left\langle FS_{ik}, x_j \right\rangle \in R^s$ condition is fulfilled, there is interconnection between function of the armament and military equipment sample and the input influence for SAM.

When designing SAM it is important to take into account the missile interaction with the external environment [10–13]. At the same time, there are sets of elements of SAM that the *ADO* (array of designed objects) interacts with during operation and the class of objects describing the environment *AEO* (array of environmental objects).



Operational and tactical requirements for the air defense system, results of the implementation of the avant- project

System decomposition of the problem of air defense system designing, determining the set of elements of ADS that the SAM interacts with, *ADO* (*an array of designed objects*)

An analysis of the operation of the guidance loop elements, the formation of functions set and their encapsulation into objects of the class, *AEO* (*an array of environmental objects*)

Structure formation of guidance loop classes - AGL (an array of guidance loop objects)

Problem structural decomposition of the surface-to-air missile design, formation of the classes structure describing the main components of the missile - *MOM* (*main objects of missile*)

Problem functional decomposition of the surface-to-air missile design, formation a set of *SF* systemic functions describing the behavior of the SAM in the external environment

Formation of the class structure describing the main missile systems of the *MMS* (*main missile systems*)

Designing of separate systems at the level of a functional model, definition of internal functions of *MMS* classes $F(s_i)$

Integration of *MMS* classes functions into separate components of a missile - *MOM* classes.

Determining the composition of elements that provide the implementation of individual functions

Structural design of missile components - as an integrating elements process into *MOM* classes, developing models for the operation of the main missile components

Structural design of the surface-to-air missile – as a process of integrating missile components into the *AM* class, developing a model for the functioning of SAM

Structural design of the guidance loop - as a process of integrating surface-to-air missile into the air defense system, the development of a composite model of the functioning of the ADS in the guidance loop

Fig. 3. General structure scheme of the synthesis method of object-oriented model of guidance loop the path of surface-to-air missile

Formation of the structure of the guidance loop classes – *AGL* (*array of guidance loop objects*)

$$AGL = AM \cup ADO \cup AEO . \quad (9)$$

The structural decomposition of the design problem of SAM, the formation of the class structure, describes the main components of the missile – *MOM* (main objects of missile), is carried out on the basis of the definition of the outline of future-technology SAM

$$MOM = \{b_1, b_2, ..., b_6\} , \quad (10)$$

where b_1 – active radar target seeker; b_2 – block pulsed SPRE; b_3 –guidance system; b_4 – warhead; b_5 – jet engine; b_6 – aerosurfaces actuators system.

Functional decomposition of the design problem of SAM, the formation of a set of *SF* system functions, describing the behavior of future-technology SAM in the external environment

$$SF = \{f_{s1}, f_{s1}, ..., f_{sm}\} . \tag{11}$$

This process is carried out by describing the stages of the flight of the missile and forming a vector of the initial parameters (providing a simulation of its 6-dimensional motion).

The stages in forming the structure of the classes describing the main missile systems (*MMS*) and the design of separate systems at the level of the functional model are connected with the block-hierarchical approach to design.

The block-hierarchical design paradigm has historically developed so that groups of developers specializing in the design of separate systems, followed by their aggregation. Therefore, when implementing object-oriented design, this approach is retained.

As an example, it is possible to refer the functional model of the flight-control system, which structure of *MMS* classes that can be represented in form

$$MMS = \{s_1, s_2, s_3\} , \tag{12}$$

where s_1 – guidance system; s_2 – control system; s_3 – navigation system.

When designing separate systems of SAM, a functional scheme of the corresponding system is developed. For example, there are many internal functions of the control system

$$F(s_2) = (F_1, F_2, ..., F_j) . \tag{13}$$

A set of internal class *MMS* functions

$$FMMC(s) = \bigcup_{i=1}^{3} F(s_i) . \tag{14}$$

The phase of integrating the system and internal functions of *MMS* classes into separate components of the missile – the *MOM* classes represents a transfer from system to structural design of missile equipment.

As a result of this phase, a functional scheme of the airborne part of missile flight-control system is being developed (Fig. 4). The process for determining the composition of elements that provide the implementation of separate functions currently has a fundamental difference from the similar processes used in the development of existing SAM.

This is due to an increase in the level of encapsulation of functions in the basic elements of SAM.

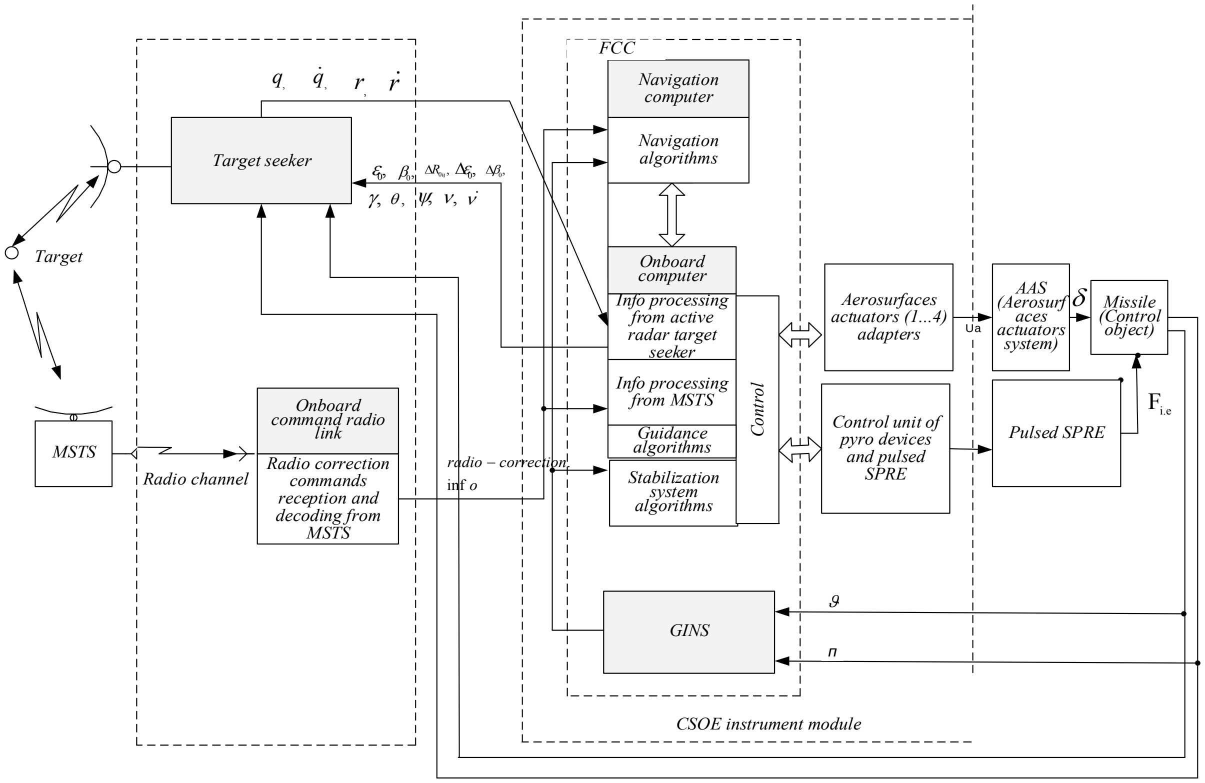


Fig. 4. Onboard control loop block diagram

Under the basic element is understood part of a system with determined functions (which has a certain behavior) and is not subject to further breakdown within the framework of the problem being solved.

Currently, the developer uses the objects that implement a large number of functions as the basic elements. Main part of the functions that define the data processing are encapsulated in the “element”.

Formation of sets of A basic elements and their $F(A)$ functions allows getting to a higher level of structural design of missile components by integrating basic elements into *MOM* classes. The *CSHM* class (control system of homing missile) is considered as an example of a stabilization system includes a set of elements

$$CSHM = \{a_1, a_2, ..., a_m\}. \qquad (15)$$

Accordingly, the set of functions *FCSHM* (functions CSHM) implemented by a set of elements

$$FCSHM(A) = \bigcup_{i=1}^{m} F(a_i). \qquad (16)$$

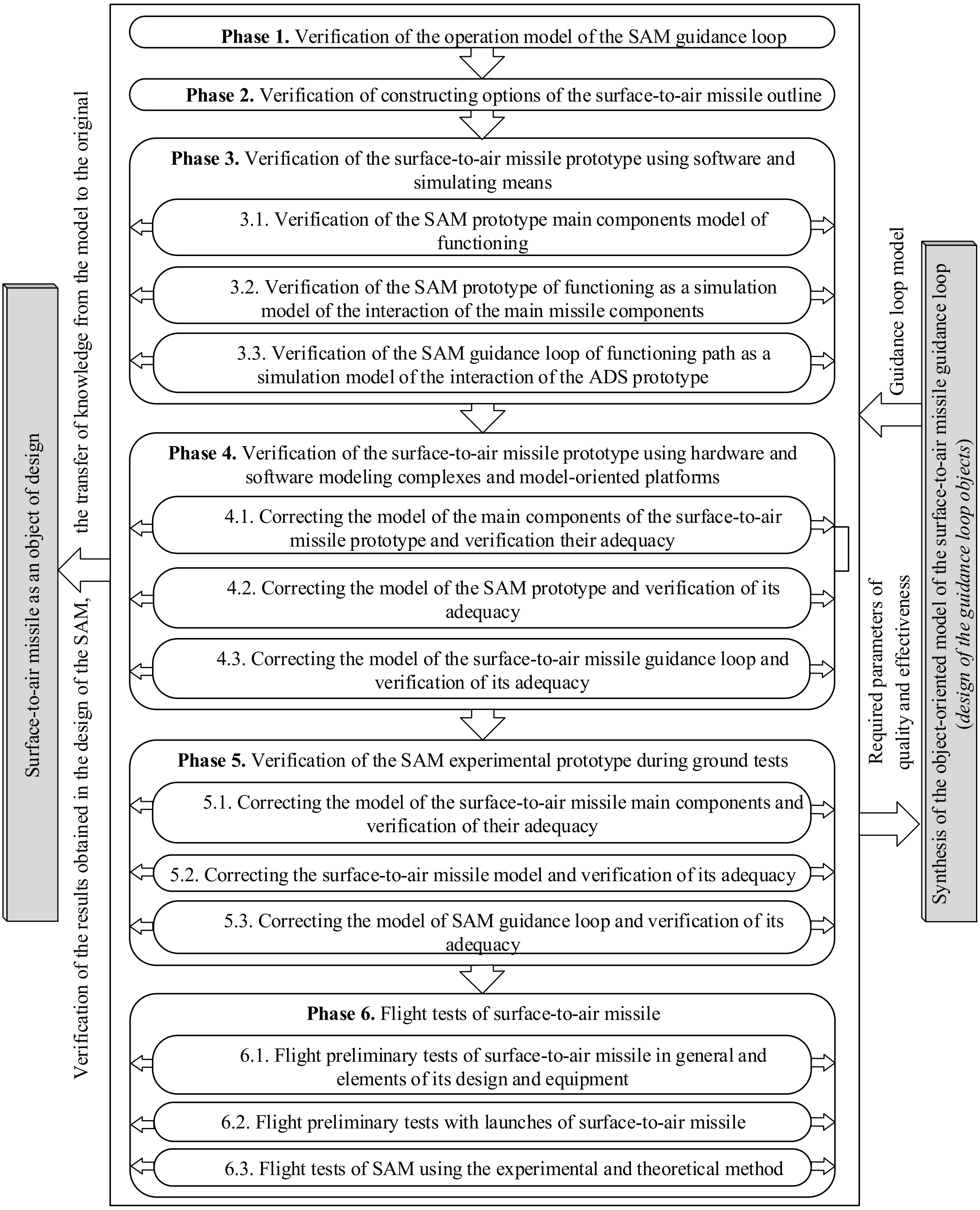


Fig. 5. General srtuctural scheme of the modified method of electronic launches

The presence of sets of basic elements and the functions performed by them allows proceeding to the next level of structural design – the development of devices included in separate components of the missile – *MOM* classes.

Next phase of structural design are related to the aggregation of the guidance loop model at higher levels.

The next important step of OO-design (Fig. 1) is a test / simulation modeling. From a cognitive point of view, there are no serious differences between the tests of SAM as a physical object and the simulation of SAM as some virtual object. When providing the necessary model adequacy to the real object, the differences become insignificant. The main thing here is that the presence of a ratio between test processes and simulation model changes the logic of creating complex military technical systems.

Experimental-theoretical method of studying the characteristics of the guidance loop becomes the main one, and the research itself, combined into a modified method of electronic launches, forms a single complex of full-size and model tests at all stages of the creation of SAM. The general structure of the modified method of electronic launches is shown in Fig. 5.

The ratio between the total number of n tests and the number of n_p real launches is determined by the value of the coefficient of r correlation between the results of real launches of SAM and their simulation. When the ratio between the volumes of real launches and the number of runs of the $n_p \ll n_m$ model [5]:

$$\frac{n}{n_p} = \frac{1}{1 - r^2}\,. \tag{17}$$

Thus, a combined estimate compared to an estimate obtained by the results of real launches, is acceptable for accuracy or efficiency only when a high correlation between the start and simulation results is ensured.

The adequacy of the design model of SAM guidance loop and the adequacy of the model of external influences should be ensured.

During designing, with the accumulation of knowledge about the projected system to increase the adequacy of simulation models, the transition to hardware-software models is carried out. From a systemic point of view, in the initial two phases of the modified method of electronic launches, an imitation model of the design of SAM outline, that serves as a model for the formalization of knowledge, is created.

The third phase of research is carried out in order to refine the mathematical model, taking into account the practical implementation of missile systems. Currently, the transfer of the "center of gravity" of the project tasks from the stage of working design to the stage of sketch design (engineering), during which a prototype model is formed. This model is high-level representation of projected SAM. In this case, the verification task of the characteristics of complex systems in the initial stages of development becomes actual. To do this, a special model-oriented platform is used. An example of such platforms can be the automatic design system Agilent SystemVue, which is used to design and simulate the working conditions of SAM radio equipment [14].

The next phase of electronic launches method is related to the subsequent increase in the adequacy of the model.

The use of modern SAM data sensors with digital output creates the possibility of further increasing the adequacy of the hardware-software model by replacing the missile model with the electronic launch of the missile model for which the flight conditions are modeled.

New situation is realized in which, all the main components of guidance loop are represented by real objects and modeling errors are related to the simulation of external environmental influences and system functions of the missile.

The phase of previous flight tests is aimed at interaction of the missile with the external environment, confirmation of the given tactical and technical characterictics of missile, calibration of the hardware-software model of the guidance loop.

The phase of flight acceptance tests is organized in accordance with the requirements of the customer, which is responsible for their conduct.

Conclusion

The classic block-hierarchical design paradigm and cascade (waterfall) life cycle model do not provide enough design efficiency. The conclusion is made on the need to use a spiral (evolutionary) object-oriented model for SAM designing using an object-oriented approach and a modified method of "electronic launches" as technologies that integrate within the framework of common approaches the issue of testing and simulation modeling of SAM at all stages of designing.

Список літератури

1. Демидов Б.А. Системная методология планирования развития, предпроектных исследований и внешнего проектирования вооружения и военной техники / Б.А. Демидов. – К.: ИД "Стилос", 2011. – 464 с.

2. Системно-концептуальные основы методологии военно-научных исследований и решения прикладных военно-технических проблем: монография. Кн. 2 / Б.А. Демидов, С.Н. Остапенко, М.И. Луханин, А.Ф. Величко, М.В. Науменко, О.А. Хмелевская, Т.И. Филякова; под ред. Б.А. Демидова. – Тверь, 2014. – 688 с.

3. Системно-концептуальные основы методологии военно-научных исследований и решения прикладных военно-технических проблем: монография. Кн. 3 / Б.А. Демидов, С.Н. Остапенко, М.И. Луханин, А.Ф. Величко, М.В. Науменко, О.А. Хмелевская, Т.И. Филякова; под ред. Б.А. Демидова. – Тверь, 2014. – 560 с.

4. Методические основы системных исследований и решения проблем технического оснащения вооруженных сил государства: монография. Кн. 2 / Б.А. Демидов, О.П. Коростелев, С.Н. Остапенко, Д.А. Гриб, В.Б. Вагапов, А.Ф. Величко, С.А. Олизаренко; под ред. Б.А. Демидова. – К.: Издательский дом “Стилос”, 2016. – 640 с.

5. Ашурбейли И.Р. Сложные радиоэлектронные системы вооружения. Планирование и управление созданием. Кн. 2 / И.Р. Ашурбейли, А.И. Лаговиер, С.П Соколов. – М.: Радиотехника, 2010. – 438 с.

6. Герасимов С.В. Техніко-економічне обґрунтування розробки (модернізації, закупівлі) складних технічних комплексів / С.В. Герасимов, А.М. Клименко, Т.А. Пінчук // Збірник наукових праць Харківського університету Повітряних Сил. – Х.: ХУПС, 2010. – Вип. 1 (23). – С. 111-115.

7. Турінський О.В. Методика обґрунтування множин характеристик перспективних зенітних ракетних комплексів і визначення їх допустимих змін / О.В. Турінський // Наука і техніка Повітряних Сил Збройних Сил України. – 2018. – № 2(31). – С. 67-72. https://doi.org/10.30748/nitps.2018.31.08.

8. Turinskyi O.V. Development of a method for analyzing the composition and characteristics of advanced weapons samples for the Air Force of Ukraine / O.V. Turinskyi // Science and Technology of the Air Force of Ukraine. – 2018. – No. 4(33). – P. 16-20. https://doi.org/10.30748/nitps.2018.33.02.

9. Скорик А.Б. Аналіз загальної методології формування вимог до військово-технічних систем і озброєння ЗРВ. Частина 1. Еволюційний розвиток оперативно-тактичних вимог / А.Б. Скорик, Б.О. Демідов, П.А. Дранник // Системи озброєння і військова техніка. – 2010. – № 3(23). – С. 75-82.

10. Аналіз особливостей побудови і застосування перспективних систем управління високоточною зброєю. Активні головки самонаведення / А.Б. Скорик, М.І. Камчатний, Є.В. Моргун, І.В. Помогаєв, Р.В. Іщенко, М.І. Щоголєв // Системи озброєння і військова техніка. – 2018. – № 3(55). – С. 36-43. https://doi.org/10.30748/soivt.2018.55.05.

11. Высокоточные системы самонаведения. Расчет и проектирование вычислительный эксперимент / К.А. Пупков, Н.Д. Егупов, Л.В. Колесников, Д.В. Мельников, А.И. Трофимов. – М.: ФИЗМАТЛИТ, 2011. – 512 с.

12. Проектирование зенитных управляемых ракет / Под ред. И.С.Голубева, В.Г.Светлова. – Москва: Издательство МАИ, 1999. – 725 с.

13. Qiping Chu Advances in Aerospace Guidance, Navigation and Control / Qiping Chu, Bob Mulder, Daniel Choukroun, Erik-Jan van Kampen, Coen de Visser, Gertjan Looye // Selected Papers of the Second CEAS Specialist Conference on Guidance, Navigation and Control. – Springer Heidelberg New York. – 2013. – P. 782.

14. Динчин Лу. Решение проблем проектирования и тестирования РЛС и средств РЭБ с помощью моделирования в САПР Agilent SystemVue / Динчин Лу //Современная электроника. – М.: Издательство “СТА-ПРЕСС”, 2013. – № 8. – С. 76-78.

15. Object-Oriented Analysis and Design with Applications (3rd Edition) / Grady Booch, Robert A. Maksimchuk, Michael W. Engle, Bobbi J. Young, Jim Conallen, Kelli A. Houston. – Westfold. Addison-Wesley Professional, 2007. – 720 p.

References

1. Demidov, B.A. (2011), “*Sistemnaja metodologija planirovanija razvitija, predproektnyh issledovanij i vneshnego proektirovanija vooruzhenija i voennoj tehniki*” [*System methodology of development planning, pre-project research and external design of weapons and military equipment*], Stilos, Kyiv, 464 p.

2. Demidov, B.A., Ostapenko, S.N., Lukhanyn, M.Y., Velychko, A.F., Naumenko, M.V., Khmelevskaja, O.A. and Fyljakova, T.Y. (2014), “*Sistemno-kontseptual'nyye osnovy metodologii voyenno-nauchnykh issledovaniy i resheniya prikladnykh voyenno-tekhnicheskikh problem: monografiya. Kn. 2*” [*Systematic conceptual foundations of the methodology of military science research and solving applied military technical problems: Monograph. Book 2*], Tver, 688 p.

3. Demidov, B.A., Ostapenko, S.N., Lukhanyn, M.Y., Velychko, A.F., Naumenko, M.V., Khmelevskaja, O.A. and Fyljakova, T.Y. (2014), “*Sistemno-kontseptual'nyye osnovy metodologii voyenno-nauchnykh issledovaniy i resheniya prikladnykh voyenno-tekhnicheskikh problem: monografiya. Kn. 3*” [*Systematic conceptual foundations of the methodology of military science research and solving applied military technical problems: monograph. Book 3*], Tver, 560 p.

4. Demydov, B.A., Korostelev, O.P., Ostapenko, S.N., Grib, D.A., Vaghapov, V.B., Velychko, A.F. and Olyzarenko, S.A. (2016), “*Metodicheskiye osnovy sistemnykh issledovaniy i resheniya problem tekhnicheskogo osnashcheniya vooruzhennykh sil gosudarstva: monografiya. Kn. 2*” [*Methodical foundations of system research and solving the problems of technical equipment of the armed forces of the state: monograph. Book 2*], Stilos, Kyiv, 640 p.

5. Ashurbeyli, I.R., Laghovyer, A.Y. and Sokolov, S.P. (2010), “*Slozhnyye radioelektronnyye sistemy vooruzheniya. Planirovaniye i upravleniye sozdaniyem: Kn. 2*” [*Complicated electronic weapons systems. Planning and creation management: Book 2*], Radiotekhnika, Moscow, 438 p.

6. Herasymov, S.V., Klimenko, A.M. and Pinchuk, T.A. (2010), “Tekhniko-ekonomichne obgruntuvannia rozrobky (modernizatsii, zakupivli) skladnykh tekhnichnykh kompleksiv” [Feasibility study on the development (modernization, procurement) of complex technical complexes], *Scientific Works of Kharkiv National Air Force University*, No. 1(23), pp. 111-115.

7. Turinskyi, O.V. (2018), “Metodyka obgruntuvannia mnozhyn kharakterystyk perspektyvnykh zenitnykh raketnykh kompleksiv i vyznachennia yikh dopustymykh zmin” [Methodology of sets substantiation of promising anti-aircraft missile systems and determination of their permissible variation], *Science and Technology of the Air Force of Ukraine*, No. 2(31), pp. 67-72. https://doi.org/10.30748/nitps.2018.31.08.

8. Turinskyi, O.V. (2018), Development of a method for analyzing the composition and characteristics of advanced weapons samples for the Air Force of Ukraine, *Science and Technology of the Air Force of Ukraine*, No. 4(33), pp. 16-20. https://doi.org/10.30748/nitps.2018.33.02.

9. Skoryk, A.B., Demidov, B.O. and Drannik, P.A. (2010), “Analiz zahalnoi metodolohii formuvannia vymoh do viiskovo-tekhnichnykh system i ozbroiennia ZRV. Chast. 1. Evoliutsiinyi rozvytok operatyvno-taktychnykh vymoh” [Analysis of the general methodology of forming requirements for military-technical systems and armament of anti-aircraft missile troops. Part 1. Evolutionary development of operational tactical requirements], *Systems of Arms and Military Equipment*, No. 3 (23), pp. 75-82.

10. Skoryk, A.B., Kamchatnyi, M.I., Morhun, Ye.V., Pomohaiev, I.V., Ishchenko, R.V. and Shchoholiev, M.I. (2018), “Analiz osoblyvostei pobudovy i zastosuvannia perspektyvnykh system upravlinnia vysokotochnoiu zbroieiu. Aktyvni holovky samonavedennia” [Analysis of the features of construction and using of perspective control systems of the high-precision weapons. Active seeker], Systems of Arms and Military Equipment, No. 3(55), pp. 36-43. https://doi.org/10.30748/soivt.2018.55.05.

11. Pupkov, K.A., Egupov, N.D., Kolesnikov, L.V., Melnikov, D.V. and Trofimov, A.I. (2011), “*Vysokotochnyye sistemy samonavedeniya. Raschet i proyektirovaniye vychislitel'nyy eksperiment*” [*Precision self-guidance systems. Calculation and design of a computational experiment*], FIZMATLIT, Moscow, 512 p.

12. Golubeva, I.S. and Svetlova, V.G. (1999), “*Proyektirovaniye zenitnykh upravlyayemykh raket*” [*Design of anti-aircraft guided missiles*], MAI, Moscow, 725 p.

13. Qiping, Chu, Mulder, Bob, Choukroun, Daniel, van Kampen, Erik-Jan de Visser, Coen and Looye, Gertjan (2013), Advances in Aerospace Guidance, Navigation and Control, *Selected Papers of the Second CEAS Specialist Conference on Guidance, Navigation and Control*, Springer Heidelberg New York, 782 p.

14. Dinchin, Lu (2013), “Resheniye problem proyektirovaniya i testirovaniya RLS i sredstv REB s pomoshch'yu modelirovaniya v SAPR Agilent SystemVue” [Solving the problems of designing and testing radar and electronic warfare using simulation in Agilent SystemVue CAD], *Modern Electronics*, No. 8, STA-PRESS, Moscow, pp. 76-78.

15. Booch, Grady, Maksimchuk, Robert A., Engle, Michael W., Young, Bobbi J., Conallen, Jim and Houston, Kelli A. (2007), *Object-Oriented Analysis and Design with Applications*, 3rd Edition, Westfold, Addison-Wesley Professional, 720 p.

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МЕТОД ПРОЕКТУВАННЯ ЗЕНІТНИХ КЕРОВАНИХ РАКЕТ ІЗ ЗАСТОСУВАННЯМ ОБ’ЄКТНО-ОРІЄНТОВАНОГО ПІДХОДУ І ТЕХНОЛОГІЇ ЕЛЕКТРОННИХ ПУСКІВ

О.В. Турінський, А.Б. Скорик

У статті розглядаються системно-концептуальні аспекти проектування зенітних керованих ракет. Використовуючи досвід виконання проектних робіт із створення систем високоточної зброї в Україні зроблено висновки, що класична блочно-ієрархічного парадигма проектування і каскадна модель життєвого циклу вже не забезпечують достатньої ефективності процесу проектування..

Запропоновано спіральну об’єктно-орієнтовану модель проектування зенітних керованих ракет, що дозволяє підвищити ефективність проектування при скороченому обсязі контрольних льотних випробувань. Розроблено загальну структурну схему методу об'єктно-орієнтованого проектування ЗКР. Виконано формування класів, об’єктів та структур, що являються формалізованими механізмами синтезу зенітних керованих ракет, при цьому використані теоретичні засади об’єктно-орієнтованої методології проектування, що поєднує в собі процес об’єктної декомпозиції і прийоми представлення логічної, фізичної, статичної та динамічної моделі проектованої системи.

Розроблено метод синтезу об'єктно-орієнтованої моделі контуру наведення ЗКР, сформульовані і розглянуті етапи синтезу. Приведено можливий варіант побудови функціональної схеми бортового контуру управління перспективної ЗКР.

Зроблено висновок, що з пізнавальної точки зору відсутні які-небудь серйозні відмінності між випробуваннями ЗКР як фізичного об'єкту і імітаційним моделюванням ЗКР як деякого віртуального об'єкту. При забезпеченні необхідної адекватності моделі реальному об'єкту відмінності стають несуттєвими. Виходячи з цього факту декларується, що дослідно-теоретичний метод дослідження характеристик контуру наведення стає основним, а самі дослідження, що об'єднуються в модифікований метод електронних пусків утворюють єдиний комплекс натурних і модельних випробувань на усіх етапах проектування ЗКР.

***Ключові слова:** об'єктно-орієнтований синтез, контур наведення зенітних керованих ракет, проектування ЗКР, ЗРК, класи і об'єкти моделі, метод "електронних пусків".*

МЕТОД ПРОЕКТИРОВАНИЯ ЗЕНИТНЫХ УПРАВЛЯЕМЫХ РАКЕТ С ИСПОЛЬЗОВАНИЕМ ОБЪЕКТНО-ОРИЕНТИРОВАННОГО ПОДХОДА И ТЕХНОЛОГИИ ЭЛЕКТРОННОГО ПУСКА

А.В. Туринский, А.Б. Скорик

В статье рассматриваются системно-концептуальные аспекты проектирования ЗУР. Используя опыт выполнения проектных работ по созданию систем высокоточного оружия в Украине сделаны выводы, что классическая блочно-иерархическая парадигма проектирования и каскадная модель жизненного цикла уже не обеспечивают достаточной эффективности процесса проектирования.

Предложена спиральная объектно-ориентированная модель проектирования ЗУР, позволяющая повысить эффективность проектирования при сокращенном объеме контрольных летных испытаний. Разработана общая структурная схема метода ОО-проектирования ЗУР. Выполнено формирование классов, объектов и структур, являющихся формализованными механизмами синтеза зенитных управляемых ракет, при этом использованы теоретические основы объектно-ориентированной методологии проектирования, сочетающей в себе процесс объектной декомпозиции и приемы представления логической, физической, статической и динамической модели проектируемой системы.

Разработан метод синтеза объектно-ориентированной модели контура наведения ЗУР, сформулированы и рассмотрены этапы синтеза. Предложен возможный вариант построения функциональной схемы бортового контура управления перспективной ЗУР.

Сделан вывод, что с познавательной точки зрения отсутствуют какие-либо серьезные различия между испытаниями ЗУР как физического объекта и имитационным моделированием ЗУР как некоторого виртуального объекта. При обеспечении необходимой адекватности модели реальному объекту различия становятся несущественными. Исходя из этого факта декларируется, что опытно-теоретический метод исследования характеристик ЗУР становится основным, а сами исследования, объединяются в модифицированный метод электронных пусков и образуют единый комплекс натурных и модельных испытаний на всех этапах проектирования ЗУР.

***Ключевые слова**: объектно-ориентированный синтез, контур наведения зенитных управляемых ракет, проектирование ЗУР, ЗРК, классы и объекты модели, метод "электронных пусков".*