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Adaptation of corporate model of Ukrainian aircraft product life cycle to the international methodology of systems engineering

S. Kryvova[1] • **C. Zvorykin**[2] • **S. Trubachev**[1]

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Problems. *Under the present-day conditions, the preservation of competences of Ukrainian aircraft construction enterprises will be determined by the possibility of enterprises attracting to participation in international cooperation programs and projects. But this is possible only on the condition of prior harmonization of the product development methodology adopted in Ukrainian aircraft construction to that used in the international aircraft construction projects.*

Purose. *The main goal of this article is to determine the ability and ways of adapting the corporate model of life cycle of aircraft engineering projects by Ukrainian aircraft construction enterprises to modern global aircraft construction practices.*

Implementation methodology. *The research methodology predicted the identification of the main modern trends in the field of system engineering for the creation of a science-intensive product, as well as the analysis of concepts of presenting the life cycle of complex technical systems in international regulatory documents, industry regulations, guidelines and other information sources. Criteria for perspective of using the identified informational and normative sources as close analogues for the development of one's own corporate model of life cycle of an aircraft construction product were identified. On the basis of the criterion analysis of researched concepts of the life cycle of complex technical systems representing, the requirements were formed, which formed the basis of the concept of one's own corporate model of life cycle of the aircraft construction product.*

The results. *The result of conducted research was the proposed concept of a corporate model of the life cycle of an aircraft construction product manufactured in Ukraine, which takes into account the international experience and best practices of leading aircraft construction companies, including focusing on the experience accumulated by domestic aircraft manufacturers.*

Conclusions. *According to the results of analysis of advanced world practices in the field of creating a science-intensive product, an own corporate model of the life cycle of an aircraft product manufactured in Ukraine was proposed. In the future, on the basis of this model, a system for creating an aircraft product can be built and developed, which will be harmonized with existing world practices and will allow the domestic aircraft construction enterprises to fight for participation in international programs and projects.*

Keywords: *system engineering, complex technical system, aircraft construction product, science-intensive product, life cycle of science-intensive product.*

1. Introduction

Until February 2022, tens of thousands of employees worked at aircraft construction and aircraft repair enterprises of Ukraine, and the enterprises had more than half a century of experience in the development and production of aircraft, engines and aggregates, carried out the modernization and maintenance of dozens of types of aviation equipment.

At these enterprises, a system of development and production of aviation equipment was formed and maintained at a sufficient level, which was based on the main provisions of international aviation rules and standards of airworthiness.

Nevertheless, individual provisions of domestic regu latory documents were not sufficiently adapted to a number of basic international regulations in this field. This was and remains one of the essential reasons that made it difficult for Ukrainian aviation enterprises to participate and cooperate in relevant international programs and projects.

In the new realities, the preservation of aircraft-building competences will depend to an even greater extent

✉ *S.G. Kryvova*
skrivova@ukr.net

[1] *Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine*

[2] *"Ukrainian Research Institute of Aviation Technology" JSC, Kyiv, Ukraine*

on the possibilities of attracting Ukrainian enterprises to participate in international cooperation programs and projects.

These possibilities will largely be determined by the degree of harmonization of the product development methodology adopted in Ukrainian aircraft construction to that used in international aircraft construction projects.

At the top of imaginary methodological pyramid of the aviation equipment creation are ideas formed in the international environment in the last few decades regarding the model of life cycle of a complex technical system - a science-intensive product.

Thus, the issue of assessing the ability to adapt existing practices in the Ukrainian aircraft industry for the development and production of aircraft products to those generally accepted in the international aircraft industry is an urgent task.

2. Analysis of literary data and statement of the problem

In the article, an analysis of informational and regulatory documentation was carried out in the field of presenting the life cycle of a science-intensive project: domestic regulatory documents (including relevant Soviet standards, interstate standards adopted by the Interstate Council for Standardization, Metrology and Certification CIS1, which included the Derzhspozhivstandard of Ukraine); international regulatory documents, in particular standards of the International Organization for Standardization (ISO), AAP standards of the North Atlantic Treaty Organization (NATO), guidance of the US Department of Defense (DoD), ECSS standards of the European Cooperation for Standardization in the field of space technology; general methodological guidelines (PMBOK Guide, SEBoK); other reference literature. Also, some regulatory documents which are in force in the environment of the Interstate Aviation Committee (IAC) were studied.

For a long period in Ukraine, the main standard that established the stages of development of design documentation for products of all industries and the stages of work execution was the standard GOST 2.103–68 (ST REV 208-75) ESKD “Development Stages” [1]. The life cycle of the product in the accepted sense was not considered in this standard.

Standard GOST 15.001-88 [2] from March 1, 1989 was defined as the national standard of Ukraine. In this standard the basic provisions for the development and mastering of production of new (modernized) national economic products for industrial and technical purposes were established. The standard did not regulate works related to the operation and disposal of products.

Ukrainian standard DSTU 3278-95, “System of development and supply of products for production. Basic terms and definitions”, [3] established the terms and definitions of basic concepts related to the development and delivery of products for production, which are necessary for the development of Russian-language interstate standards. “Life cycle (of products)” in this standard is defined as “a set of interrelated processes of successive changes in the state of products from the beginning of research and justification of development to the end of product operation.” Currently, some of terms of the DSTU 3278-95 standard have lost their relevance.

In 2019, the DSTU V-P 15.004:2019 “System of development and put into production the weapons and military equipments. Stages of the life cycle of weapons and military equipment” [4]” was adopted as a trial national standard with validity until October 1, 2023. During the development of this standard, the provisions of international standards DSTU ISO/IEC/IEEE 15288:2016 [5] and DSTU ISO/IEC TS 24748-1:2018 [6], which are based on system and process approaches, as well as on international terminology, were taken into account. In this standard, the model of life cycle of weapons and military equipment (WME) is based on the model of life cycle of the North Atlantic Treaty Organization (NATO) in accordance with the standards AAR-20:2015 “NATO program management frame work (NATO Life Cycle Model)” [7] and AAR-48:2013 “NATO system life cycle processes” [8], which is based on provisions of ISO/IEC/IEEE 15288. That is, according to ISO/IEC/IEEE 15288 and AAP-20, each WME product can be submitted as “the system under consideration” {see p. 4.1.48 in 15288 system-of-interest}. Each system or system element at each level of the hierarchy can be objects of a separate program or project and have its own life cycle model.

According to DSTU ISO/IEC/IEEE 15288, DSTU ISO/IEC TS 24748-1 and AAP-20, the typical stages of life cycle of WME product include the following: “concept” stage, “development” stage, “production” stage, “utilization” stage, “support” stage, “retirement” stage.

It is important to note that in NATO’s approaches, in accordance with ISO/IEC/IEEE 15288, the “concept” stage consists of two phases, that is, the “pre-concept” life cycle phase is provided for, the main purpose of which is to determine the goals that need to be achieved, and the stakeholder requirements for the “system under consideration”.

DSTU standard ISO/IEC/IEEE 15288:2016 “Systems and software engineering. Systems life cycle processes” (ISO/IEC/IEEE 15288:2015) [5] (hereinafter - DSTU 15288) is a translation of the international standard ISO/IEC/IEEE 15288:2015 “Systems and software engineering – System life cycle processes” [9]. As well as the indicated international standard, the DSTU ISO/IEC/IEEE 15288:2016 (hereinafter - DSTU 15288) is supplemented by related Ukrainian standards DSTU ISO/IEC TR 24774:2016 “System and software engineering standard. Life cycle management”. Like the specified international standard, the DSTU ISO/IEC/IEEE 15288:2016 (hereinafter - DSTU 15288) is supplemented by related Ukrainian standards DSTU ISO/IEC TR 24774:2016 “Standard Engineering of systems and software tools. Life cycle management”, instructions on process description [10], DSTU

ISO/IEC TS 24748-1:2018 “Systems and software engineering. Life cycle management. Part 1. Guidelines for life cycle management.” [11], DSTU ISO/IEC TR 24748-2: 2015 “Development of systems and software. Life cycle management. Part 2. Guidance on the application of ISO/IEC 15288 (System life cycle processes)” [12] and the DSTU standard ISO/IEC/IEEE 16326:2015 “Development of systems and software. Life cycle processes. Project management.” [13]. The DSTU 15288 standard uses an engineering and technical approach and contains a model of generalized processes describing the life cycle (LC) of man-made systems. The DSTU 15288 standard applies to the entire life cycle of systems, in particular to the stages of concept, development, progressing, utilization, maintenance and withdrawal, as well as to the acquisition and supply of systems, carried out inside or outside the organization. The DSTU 15288 standard does not establish a specific model of the LC of system, development methodology, method, model or technique. Its users are responsible for choosing the model of the LC for the project and displaying the processes, activities and tasks according to this standard.

International basic standards can include international standards - initially “draft” ISO/DIS 21500 Guidance on project management” (2011), currently ISO 21500:2021 “Project, program and portfolio management – Context and concepts” (2021)” [14], as well as related standards ISO 21502:2020 “Project, program and portfolio management – Guidance on project management” [15], ISO 21503:2022 “Project, program and portfolio management – Guidance on program management” [16], ISO 21504:2015 “Project, program and portfolio management – Guidance on portfolio management” [17] and ISO 21505:2017 “Project, program and portfolio management – Guidance on governance” [18]. The ISO 21500 standard contains a general description of principles and processes of project management. According to ISO 21500, project life cycle covers the period from the beginning of the project to its planned end or early termination. The boundaries of the project’s LC phases[1] are the points[2] of decision-making, which composition may depends on the project’s organizational environment. At the end of the last phase of LC the results should be obtained.

It is significant that the life cycle of complex technical systems according to the standards of the European Cooperation for Space Standardization (ECSS) is quite close to the life cycle of aviation equipment (AE), at least, with regards to the signs of complexity and science-intensiveness. In the ECSS standards [19], [20], [21], [22], as well as in the international standards ISO 21500, in the base of project phasing and planning the same basic principles are laid down: all projects can be divided into periods; each period is designed to advance a system or product from one baseline to another after successful completion of its characteristic activities; during these stages, mostly at the end, project acceptances are planned as milestones[3] at the project stage; each acceptance is a critical review performed by a team not directly responsible for the activity under review; the concept of the project’s LC model should be determined regarding the project phasing and planning as early as possible, taking into account available resources and technological risks. Typically, a project is broken down into seven main periods: Period 0: Mission Analysis/Needs Determination. Period A: Feasibility. Period B: Preliminary definition (project and product). Period C: Detailed definition (product). Period D: Production/Proficiency Testing. Period E: Utilization (sub-period E1 - testing and commissioning of the system; sub-period E2 - utilization). Also, period E covers mass production of repetitive products. Period F: Withdrawal.

The authors of this Work also considered two Allied Administrative Publications (AAP) of the North Atlantic Treaty Organization (NATO), namely: AAP-20:2015 “NATO program management framework (NATO Life Cycle Model)” [7] and AAP-48:2013 “NATO system life cycle processes” [8].

AAP-20 is a general guide that provides a standardized and adapted approach to program management, and is used in conjunction with AAP-48 and the SLCM document library. The AAP-48 manual defines the management processes of NATO’s SLC. The SLCM contains procedures, templates, manuals and other documents. To support management and facilitate decision-making during program/project implementation, a structured approach should be divided into stages. Stages of a typical Allied project: pre-concepts, concept, development, production, use, support, and decommissioning. This NATO LC model is based on the LCS model and explanation of the LC stages in the ISO 15288 standard within the LC concept and represents NATO’s special interpretation for NATO programs/projects and multinational and national programs/projects. The main elements of each stage are inputs, output data and input/output criteria.

General methodological guidelines for project management, “A guide to the project management body of science. (PMBOK® guide) – Sixth edition” (2017–2018) [23]–[24] and “A Guide to the Project Management Body of Knowledge (PMBOK® Guide) - Seventh Edition” (2021) [25], are methodologically almost completely consistent with ISO 21500, but offer a more comprehensive and detailed universal LC template for a technical systems project. According to the PMBOK® definition, the LC of a project is a set of phases that a project goes through from inception

[1] Phases in the ISO 21500 standard are the periods between the beginning and the end of the project, into which each project is divided. Other terms are also used for this, including “stage”, “period”, “sub-period”, etc.

[2] Other names are also used, including “control points”, “decision points”, “key decision points”, “decision gates”, “gateways”, etc.

[3] A milestone is a significant point that has already been planned or will be planned in the project

to completion. A key project management component (program) used with project phases is the phase analysis.

"Phase gates" are conducted at the end of a phase. Execution and progress of the project is checked against the project documents and business documents. The decision (for example, to continue or stop the project) is made based on the results of this check in order to make a following decision: - move to the next phase - move to the next phase with changes - stop the project - stay in this phase, - repeat the phase or its elements.

In the International Councilon Systems Engineering (INCOSE) publication "Guide to Life Cycles and Life Cycle Models" (26) the "Project stage" is used to define a set of activities and products, the delivery of which is managed as a "unit" and the completion of which is marked through the point of control management. In this definition, a project period does not necessarily represent the entire LC period – LC phases are divided into periods, each of which has a period gate.

In the "NASA systems engineering handbook, 2007" [27] it is stated that one of the main concepts used by NASA for major systems management is the program/project LC, which categorizes everything, that needs to be done to implementation of the program or project, into separate periods, separated by key decision points (Key Decision Points, KDPs).

Key decision points are events during which the authority determines the readiness of the program/project to move to the next LC phase (or to the next key decision point). The period boundaries are defined in such a way that they provide natural points for making "go" or "no-go" decisions. The LC of the program/project should provide managers with a step-by-step vision of progress achieved at points in time that meet management and budget conditions: - Pre-formulation of the program: ▪Pre-period A: Concept study. ▪ Formulation of the program: ▪ period A: Concept and technology development. ▪ Period B: Preliminary design (sketch project) and completion of the technology. - Implementation of the program: ▪ Period C: Final design and manufacturing. ▪ Period D: System assembly, integration and testing, start-up. ▪ Period E: Operation and Support. ▪ Period F: Closing.

Among the corporate management of organizations related to the aerospace industry, the corporate regulatory and management documents of the Airbus Corporation were reviewed. Among the researched standards the great interest for the Work are certain AP (Airbus Procedural) directives, procedures and instructions, means and methods (AM), in particular AP2054 - Main "New aircraft development (NAD) - Definition of a business process" [28], AP2054 Module 1 "New aircraft development (NAD) - Business process definition - Key event model" [29], AP2054 Module 2 "New aircraft development - Business process definition - Digital product reference" [30], AM2054 "Integration of design and creation. Milestones" [31]. To ensure a logical sequence in understanding the process of a new aircraft development (NAD), 4 periods are defined: Feasibility Period, Concept Period, Determi-

Table 1. Comparison of products life cycle presentation in regulatory documentation

Standard	ISO/IEC/ IEEE 15288:2015 International standards	AAP-20, AAP-48 NATO International standards	ECSS–M–30A International standard	Ukraine: DSTU V-P 15.004:2019	Ukraine: DSTU 3974-2000
Life cycle presentation (stages, periods)	LC stages: 1.Order 2.Development 3.Production 4.Utilization 5.Support 6.Retirement	LC stages: 1.Pre-concept 2.Concept 3.Development 4.Production 5.Utilization 6.Support 7.Retirement	LC periods: 0: Mission Analysis/Needs Determination A: Feasibility B: Preliminary definition (project and product) C: Detailed definition (product) D: Production/ Proficiency Testing. E: Utilization/ mass production: -E1- testing and commissioning of the system; -E2 - use of repetitive products F: Withdrawal	LC stages: 1.Concept 2.Development 3.Production 4.Utilization 5.Support 6.Withdrawal	LC stages: 1.Technical proposal 2.Sketch project 3.Technical project 4.Working design documentation of a product prototype intended for serial (mass), single production

nation Period and Development Period. These periods can also be seen as collections of relevant key events. The NAD process contains 15 consecutive processes [29].

The Standard "Standard of "United Aircraft Corporation" Public Company". Procedure for "UAC" PC aviation programs managing. General principles" (2008) [32] contains the main essence of program management and describes the principles, LC and processes used to manage programs in the aircraft industry. According to this LC standard, the program consists of three phases: starting-up, implementation and completion. Phases of the LC program consist of periods separated by "gates". At the "gate" a decision is made regarding the start of a new period or the temporary or final termination of work under the program. A set of periods and gates forms a system of making managerial decisions at the LC stages of the program product. Decisions are made taking into account the satisfaction of the main indicators of the criteria for passing the "gate". Sets of indicators and criteria at different gates and in different programs may differ.

The authors of this work conducted a comparative analysis of regulatory documentation in field of presentation of the life cycle of science-intensive complex technical systems, by the result of which the conclusions were drawn regarding the inconsistency of some domestic Ukrainian practices with international systems engineering practices (see Table 1).

3. The purpose and objectives of the research

The purpose of this study is to develop the concept of a corporate model of the life cycle of a Ukrainian aircraft construction product, which would be adapted to international regulations, regulatory documents, aircraft construction practices and, at the same time, fully take into account the domestic experience of creating unique examples of aviation equipment.

This would be followed by works on the revision of a significant array of regulatory and technical documentation of Ukrainian aviation enterprises for compliance with European (Joint Aviation Requirements) and American - the USA (Federal Aviation Regulations) aviation rules, which would greatly facilitate the possibility of certification of both developers and manufacturers of aviation equipment and its components.

This will allow the aircraft construction enterprises of Ukraine to form an effective corporate system for the creation of aircraft construction products, which would be harmonized with the existing world best practices and, thus, allow to fight for participation in international cooperative aircraft construction projects.

The following research tasks were set to achieve this goal:

1. To analyze the most representative information from the presentation of various models of life cycle of science-intensive products - complex technical systems, to identify the main modern trends in the field of system engineering of a science-intensive product creation. Determine the criteria for the perspective of using the considered informational and normative sources as close analogues of the own corporate model of life cycle of the aircraft product under development. Organize and perform expert analysis for ranking and selection of the most important evaluation criteria from among the listed indicators. Form the requirements on the basis of which a corporate model of the life cycle of the aircraft construction product will be developped, which satisfy the above-defined goal.

2. On the basis of the formulated requirements, form a conceptual model of the life cycle of the aircraft construction product, which would not contradict the model, generally accepted in the international aircraft construction environment, and the product could be manufactured at Ukrainian aircraft construction enterprises.

4. Research methods

The research methodology consisted of several stages.

The first stage consisted in analysis and identification of the main modern trends, basic practices, regulations, international regulatory documents in the field of system engineering for the creation of a science-intensive product.

It was found that the main strategy in projects for the creation of complex technical systems is the use of a combination of four modern basic approaches - the system approach, the process approach, the project approach and the risk-oriented thinking, which together ensure the guaranteed safety of use of created complex technical systems.

Also, a representative storage of information sources in this field was determined - a kind of "knowledge base" of concepts representing the life cycle of complex technical systems, with an emphasis on standards, established practices, industry regulations, international normative documents in this field.

And, finally, it was analyzed and compared the following: in what way and in what form of submission of material in various regulations and normative documents, in an explicit and implicit form, the life cycle model of a complex technical system, including an airplane, is presented. This is exactly what the above review was devoted to.

The second stage of methodological approach consisted in identification and determination of criteria for the perspective of using the identified informational and normative sources in the field of system engineering a science-intensive product creation as close analogues for the development of its own corporate model of life cycle of an aircraft construction product. These criteria should allow for the formation of the most successful, convenient for use in domestic practice model, which would satisfy the following basic conditions:

– friendly perceived by users and took into account their previous experience in this field;

Table 2. Criteria for choosing the concept of the life cycle model of a science-intensive product

	Criterion	Criterion content	Weight share of the criterion, %
Basic criteria	Presence of clearly expressed representation of system life cycle	Presence/absence of formulation of content and composition of system life cycle (phases, stages, periods, etc.).	20
	Availability of registration in form of regulatory documents (status)	Has the status: – international, national, branch, corporate; – regulation, norm, established practices, guidance, directory, etc.	20
	Compliance with modern international practices	Taking into account the system, process and project approach in reflections in the life cycle models of systems.	19
	Compliance with domestic corporate practices	Universal/specialized/special. Relevance to the topic of the Work.	19
	Relevance, ability to develop	Validity in Ukraine, obsolescence of materials, duplication by similar documents.	18
Auxiliary criteria	The presence of a pronounced form of representation	Presence/absence of system life cycle description in verbal and/or illustrative form.	3
	Availability for use	Used in current practices, available for reference. Translated into Ukrainian, valid in Ukraine.	1

– properly correspond to advanced international practices in the field of aircraft construction.

For this purpose, subject-oriented indicators corresponding to system, process and project approaches were defined, which could later be used as a broad set of criteria for evaluating the concept of life cycle model of aircraft, which is being developed:

– Clarity of the goal and solved tasks.
– Necessity, sufficiency.
– Taking into account international standards, unification and standardization.
– Compliance with domestic corporate practices.
– Systemacy, connectedness.
– Suitability, adequacy, practicality, compatibility.
– Completeness, sufficiency, optimality.
– Specificity, reasonableness.
– Logicality, consistency, correctness, traceability.
– Unambiguity, clarity, accuracy, identifiability.
– Feasibility, realizability.
– Generally accepted terminology in the international aviation environment.
– Compliance with the "world" practices.
– Coverage of the entire cycle.
– Availability of the early stages (periods) description.
– Combined form of presentation (graphic + tabular + text).
– Corporate consensus, legitimacy, validation.
– Adaptability, variability (taking into account potential future changes).
– Structuredness, blockiness, modularity.

The third stage of methodological approach consisted in the organization and execution of expert analysis for ranking and selection of the most important criteria for evaluation from among the listed indicators. For this, the leading specialists of the main aircraft manufacturing enterprises of Ukraine were involved, appropriate procedures were formed, and five main and two auxiliary expert-defined criteria for choosing the concept of the life cycle model of a science-intensive product were selected (see Table 2).

On the basis of the research results, a criterion analysis of researched concepts of life cycle models of technical systems (which includes or may include the process of "Creating new aviation equipment") was carried out, the result of which is given below.

5. Research results

5.1. About 50 information sources were analyzed, which contain information about the features of the presentation of various models of life cycle of science-intensive products - complex technical systems. As a result, the following sources can be used as analogs to present the concept of corporate model of life cycle of a construction product manufactured in Ukraine:

– Airbus management;
– UAC PC standard. Procedure for "UAC" PC aviation programs managing. General Principles 2008;
– DSTU V-P 15.004
– AAP-20, AAP-48.

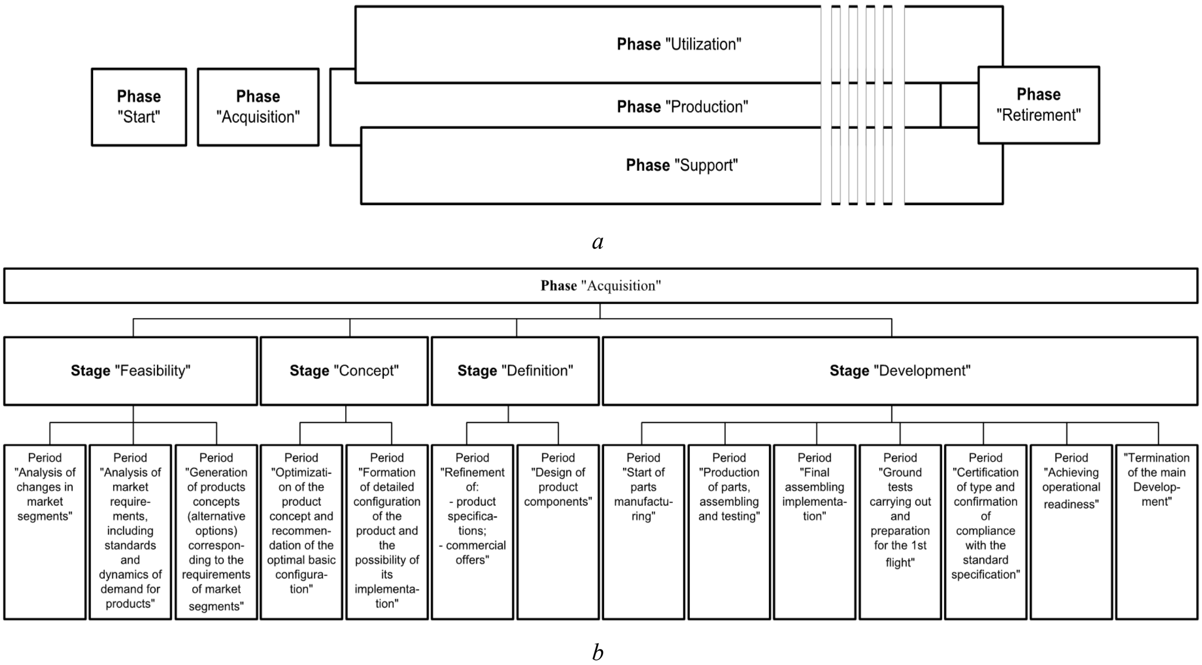

Fig. 1. Conceptual corporate model of the life cycle of aircraft construction product (*a*) and the model of development phase of this product (*b*)

Requirements were also formed, which are the basis of the concept of life cycle corporate model.

The main ones are the following:

– the model should have a sequential-cascade form of representation; to provide for stages overlapping;

– depending on complexity of the product, should have no more than 2–4 levels of hierarchical organization;

– in order to simplify the presentation, sequential visualization of stages should be provided;

– for a typical case, accept 6 stages of life cycle, which are terminologically defined as follows: “Idea” Stage; “Development” Stage; “Production” Stage; “Operation” stage, “Support” stage, “Retirement” Stage;

– stages, periods, sub-periods, etc. are formed from key events of different hierarchies (usually at first no more than 4 levels), are divided among themselves by so-called “gates” - points of key decisions making.

5.2. As a result, somewhat is simplified, but in accordance with the identified requirements the following conceptual corporate model of life cycle of an aircraft construction product produced in Ukraine was formed, which does not contradict the generally accepted representation in international aircraft construction environment (see Fig. 1).

6. Results discussion

1. The most difficult and most important phase of any project to create a complex technical system is the “Idea” phase, during which a number of iterative activities are carried out to search for and preliminary (predictive, expected, possible, etc.) determination of not only the “look” and “requirements” for the created system, but also the very needs for which the system is being created. Accordingly, the processes of searching for alternative options of possible solutions are associated with multidirectional activities, often contradicting each other, but internally connected by uncertain neural networks, the detailed study of which requires too much time and other resources. And yet, for each project, alternatives are defined, decisions are made, as a result of which mistakes are made, which are subsequently corrected, preferably as soon as possible, in order to minimize irreversible losses and reduce the costs of errors correcting. Everyone understands that the “Idea” phase is exactly that.

Despite the fact that the management of any project well understands the complexity and importance of the “Idea” phase for the technical and commercial success of the complex technical system being created, the ways and methods of achieving and obtaining effective results currently do not have generalized instructions, recommendations in the form of regulatory documents, and even more so - international standards. Exclusively within the limits of this discussion of possible approaches to the structural appearance of the “Idea” phase, the authors, based on the results of research of the present Work, can propose a generalized version presented in Fig. 2.

In the proposed version, the authors envisage a three-level hierarchical structure, the periods of which are

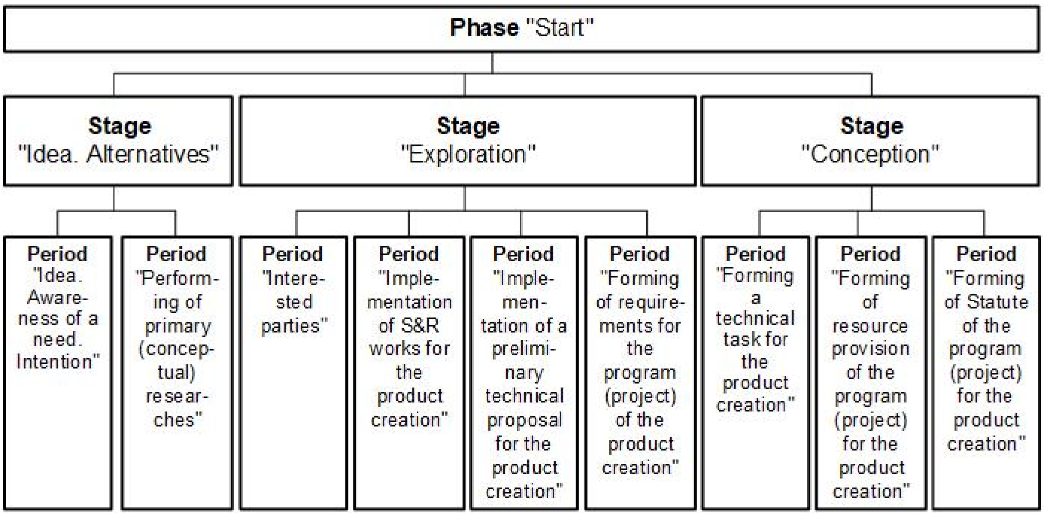

Fig. 2. Conceptual corporate model of the “Start” phase of the aircraft product life cycle

aimed at the formation of alternative options, each of which meets the expectations (interests) of existing and potential stakeholders of the future project, which has only begun with the “Start” phase. At the first stage of this phase, all possible alternatives are formed (conditionally – without restrictions), the possibilities of each of the alternatives are explored and revealed, so that in the future, already at the “Exploration” stage, interest in each of the identified alternatives of the created system can be ascertained, stakeholders can be identified and completed consideration of alternatives for which no stakeholders were found can be determined. On the other hand, such a rejection of alternative options of the system does not mean a complete rejection of rejected options - there is always an opportunity to return to them.

Finally, the “Conception” stage completes the “Start” phase by forming the initial data of the project of a complex technical system creating. It is important to emphasize that the uncertainty of the initial data of the selected alternative option at this stage remains at the highest levels. But based on the results of a comparison of all acceptable alternatives from a number of possible variants of the conceived complex technical systems, which according to the results of the “Exploration” stage in different angles, more or less, but necessarily satisfy the requirements of stakeholders, the most rated option is determined (according to expert assessments, Paretto, Delphi, etc.).

2. The “Acquisition” phase (see Fig. 1), developed for aviation equipment (as a typical complex technical systems), involves the same three-level hierarchical structure: “Phase”-“Stage”-“Period” as for the previous phase “Start”. On the other hand, the activities and results of this phase are significantly different from the works of the “Start” phase. During the periods of the first stage “Feasibility”, the feasibility of the selected option of the complex technical system being created is confirmed by studying alternative options, but much more detailed, compared to the “Start” phase. The next stage “Concept” is completed by the period, the result of which is a detailed configuration of a complex technical system and possibility of its implementation in production and during utilization. The third stage “Definition” of the “Acquisition” phase with its final stage basically completes the “design preparation of production” and forms the readiness for “technical preparation of production”.

A characteristic feature of the “Acquisition” phase is a significant increase in the importance of project management measures for the creation of a new complex technical system. As already mentioned, control points (or decision points) are the main tools of project management.

On the one hand, each business event for its completion must have a suitable solution. The majority of such decisions in the projects of complex technical systems creation have an engineering-technical or technical-economic content. The completion of a certain process is a condition for the completion of another process to which it is included - this is how the hierarchy of processes is built. It is already known that for project management it is divided into certain periods. It is also known that such a distribution is not unlimited, but restricted by the hierarchical structure that is included in the model of the life cycle of the project creation of a complex technical system. Three levels of hierarchy are justified in the present Work for the projects of aviation equipment creation. As a result, a process is distinguished in the project, which begins together with a certain period and ends also with the same period. This process includes other processes of lower hierarchical levels.

Each process of the period starts after the corresponding decision is made. After this period process is completed, a decision must also be made. According to international standards, this should be one of five possible decisions regarding the future state of the project.

The decision regarding the completed process of a period must be made based on the results of the input processes of this period. Two types of achieved results can be distinguished here:

– based on estimates of the results obtained;

– based on estimates of the project work plans execution.

3. The evaluation of obtained results of the completed period process is usually based on criteria[4] and limitations, which are usually represented by certain, predetermined values of important indicators, which are pre-determined as having a significant impact on the success of the project of creating a complex technical system. The choice (assignment) of the criteria themselves, the values of the criteria that must be achieved and relative (relative) importance of the criteria for the success of the project of creating a complex technical system - all this is an area of significant uncertainty. Solving the problems of uncertainty in the characteristics of criteria for evaluating results (especially for multi-criteria evaluations) will be the subject of further publications. The easiest way to solve the problems of uncertainty is to use the practical experience and competence of experts who participate in the evaluation process and people who make decisions about the future state of the project (as a rule, these are representatives of the highest management). Moreover, decision-makers can both take into account the expert conclusions regarding rational decisions, and not take into account such conclusions, at that they may based solely on their own experience, cognitive skills[5] and preferences.

In order to increase the efficiency of decisions regarding the state of the project of a complex technical system creating, regulatory and methodological support is needed to determine the competent subjects which are able to conduct an examination based on results of the work performed during the project stage and which make decisions based on the results of the examination.

4. Evaluation of results of completed process of the period, which are obtained as a result of the implementation of work plans, is usually carried out on the basis of a comparison of intended terms of the work completion schedules with the actual dates of the results obtaining. During the evaluation, the existing uncertainty regarding productivity, resource provision, personnel qualifications, and finally, errors due to work at previous stages, are taken into account. On the other hand, usually all methodological approaches for expert provision of decision-makers are well known.

5. A characteristic feature of the life cycle of projects of complex technical systems are relatively short periods of phases related to the idea and conception of the future complex technical system (“Start” phase), as well as intended for definition and development of CTS created (“Acquisition” phase) in comparison with subsequent periods: “Production”, “Utilization” and “Support” phases (see Fig. 1 *a*).

Conclusions

In the result of analysis of use of the most successful world practices in the field of creating a science-intensive product, carried out according to the developed methodology, the following is achieved:

1. requirements for the development of an own corporate model of life cycle of an aircraft product manufactured in Ukraine are identified;

2. the concept of a corporate model of life cycle of an aircraft product manufactured in Ukraine is proposed, which takes into account the international experience and best practices of leading aircraft construction companies, including with a focus on the experience accumulated by domestic aircraft manufacturers.

On the basis of this model, a system for creating an aircraft construction product can be built and developed, which will be harmonized with existing global practices and will allow domestic aircraft construction enterprises to fight for participation in international programs and projects.

List of abbreviations

AE – Aircraft Equipment
GOST – State standard (USSR, RF)
DSTU – State standard of Ukraine
LC – Life Cycle
IAC – Interstate Aviation Committee (USSR, RF)
CTS – Complex Technical System
AAP – Allied Administrative Publication
DoD – Department of Defense of the USA
ECSS – European Cooperation for Space Standardization
FAR – Federal Aviation Regulations (USA)
IEC – International Electrotechnical Commission
IEEE – Institute of Electrical and Electronics Engineers
INCOSE – International Councilon Systems Engineering
ISO – International Organization for Standardization
JAR – Joint Aviation (European) Requirements
NATO – North Atlantic Treaty Organization
PMBOK – Project Management Body of Knowledge
SEBoK – Systems Engineering Body of Knowledge
SLC – System Life Cycle.

[4] A criterion is an indicator or a rule by which various options for recommendations regarding decision alternatives are arranged in the order of their desirability and the best of them is selected. A criterion is a certain function of a decision recommendation that allows you to assess quantitatively its feasibility. The criteria are applied at various stages of preparing recommendations to the person making the decision: during the ranking of goals, assessment the level of goals achievement; during the selection and determination of effectiveness of means used in this regard and in relation to the resources distribution.

[5] Cognitive skills are a set of skills that people possess when it comes to learning certain information. Cognitive skills are directly related to intelligence, learning and human development.

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Адаптація корпоративної моделі життєвого циклу українського авіабудівного продукту до міжнародної методології системної інженерії

С. Кривова[1] • К. Зворикін[2] • С. Трубачев[1]

[1] *КПІ ім. Ігоря Сікорського, Київ, Україна*

[2] *АТ "Український науково-дослідний інститут авіаційної технології", Київ, Україна*

Проблематика. *В сучасних умовах збереження компетенцій українських авіабудівних підприємств визначатиметься можливістю залучення підприємств до участі у міжнародних коопераційних програмах і проєктах. А це можливе лише за умови попередньої гармонізації методології розроблення продукту прийнятої в українському авіабудуванні до такої, що використовується в міжнародних авіабудівних проєктах.*

Мета. *Основною метою цієї статті є визначення спроможності та шляхів адаптації корпоративної моделі життєвого циклу проєктів створення авіаційної техніки українськими авіабудівними підприємствами до сучасних світових авіабудівних практик.*

Методика реалізації. *Методика дослідження передбачала виявлення основних сучасних тенденцій в області системної інженерії створення наукоємного продукта, а також аналіз концепцій представлення життєвого циклу складних технічних систем в міжнародних нормативних документах, галузевих регламентах, керівництвах і інших інформаційних джерелах. Були виявлені критерії перспективності використання виявлених інформаційних, нормативних джерел в якості близьких аналогів для розробки власної корпоративної моделі життєвого циклу авіабудівного продукту. На основі проведеного критеріального аналізу досліджених концепцій представлення життєвого циклу складних технічних систем були сформовані вимоги, покладені в основу концепції власної корпоративної моделі життєвого циклу авіабудівного продукту.*

Результати. *Результатом проведених досліджень стала запропонована концепція корпоративної моделі життєвого циклу авіабудівного продукту, що виробляється в Україні, яка враховує міжнародний досвід і передові практики провідних авіабудівних фірм, в тому числі з орієнтацією на досвід накопичений вітчизняними авіабудівниками.*

Висновки. *За результатами аналізу передових світових практик в області створення наукоємного продукту була запропонована власна корпоративна модель життєвого циклу авіабудівного продукту, що виробляється в Україні. У майбутньому на базі цієї моделі може бути побудована і розвинута система створення авіабудівного продукту, яка буде гармонізована з існуючими світовими практиками і дозволить підприємствам вітчизняного авіабудування боротися за участь в міжнародних програмах і проєктах.*

Ключові слова: *системна інженерія, складна технічна система, авіабудівний продукт, наукоємний продукт, життєвий цикл наукоємного продукту.*