Innovative production of dual-use products, including agricultural machinery

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Abstract. The scientific article considers the actual aspects of the development of intelligent robotics and innovative machine-building production of dual-use goods and technologies in the defense-industrial complex of the Russian Federation, as well as the areas of application, key technologies and needs of intelligent robots, and explains the important place of intelligent robots in the future of the machine-building industry, the functions of control of intelligent robots, perception and interaction between humans and computers on the basis of technology, the use of intelligent robots in the defense-industrial complex of the Russian Federation. The aim of the study is to present to the scientific community the functional-cost analysis of unmanned aerial vehicles and build a mathematical model of inter-industry interactions arising in the innovative production of high-precision and intelligent robots. Research methods: the article used such methods of cognition of materials as analysis, synthesis, deduction and modeling. Main results of the research: The scientific article presents the author's view on the solution of the actual problem of uninterrupted production and development of unmanned aerial vehicles that can be used as dual-use goods and technologies.

1 Introduction

Intelligent robotics and innovative mechanical engineering of dual-use goods and technologies is a field that combines the development of high-precision and autonomous robots using advanced technologies and innovative approaches in mechanical engineering. Intelligent robotics includes the design and development of robots that can perform complex tasks, make decisions based on data analysis, and interact with the environment (in the air and on the ground) and people. Innovative engineering of dual-use goods and technologies is focused on creating versatile and multifunctional devices that can be used for both civilian and military purposes. Such technologies may include: sensors; control systems; components with a high degree of autonomy and self-adaptation. The study of this subject area will help unlock the potential of using intelligent robots and innovative technologies to increase

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production efficiency, improve the quality of life of people and ensure the safety of society. The critical analysis of scientific literature on the research topic includes several key aspects: the study of specific technologies such as drones (military drones, cyber warfare technologies); cybernetic systems; artificial intelligence and others. A critical analysis of the scientific literature emphasizes both the potential for innovation and the complexities and risks associated with the development and application of dual-use goods and technologies. According to Bin He "robot is not only the key support equipment of advanced manufacturing, but also an important entry point for improving the human way of life" [1]. Zaitceva I., Andrievsky B. in the research paper "Methods of Intelligent Control in Mechatronics and Robotic Engineering: A Survey" outlined the main problems and trends to improve the control methods of intelligent robots [2].

Modern technologies are actively developing, and robotics is becoming more and more intelligent and advanced. Intelligent robots are devices that have the ability to independently analyze information, make decisions, and perform complex tasks (without outside intervention). They can interact with their environment, learn and improve their skills over time. Artificial intelligence and robotics are one of the discussed subjects of research by domestic and foreign scientists. Russian machine-building enterprises, under the conditions of a special operation, receive new government orders for the production of dual-use goods and technologies. Design bureaus develop new approaches to solve new problems, modernize existing models [3]. In the process of production of unmanned aerial vehicles (hereinafter - UAVs) inter-sectoral interactions arise, which allow machine-building enterprises to create new jobs in scientific institutes and other institutions of the national economy of the country [4-8]. The scientific problem considered in the framework of this scientific article is the uninterrupted innovative production of intelligent robots and dual-purpose UAVs.

Machine learning plays a key role in modern industrial business process safety strategy. Machine learning can be used to create new monitoring and anomaly detection systems to help prevent potential security threats to industrial plants. Machine learning technologies are also used to analyze large amounts of data and identify patterns, which helps in predicting potential incidents and taking security measures in advance. In addition, machine learning is able to process information quickly and accurately, allowing you to respond quickly to threats and improve the overall security of your industrial plant.

2 Materials and Methods

The research presented in this paper was based on scientific articles published in scientific journals on robotics, aviation and mechanical engineering (IEEE Transactions on Robotics; Journal of Intelligent & Robotic Systems; Journal of Aircraft; Journal of Mechanical Design). The authors of the research paper reviewed major works on robotics, mechanical engineering and aviation covering theoretical foundations and practical aspects ("Introduction to Robotics: Mechanics and Control" by John J. Craig, "Aircraft Design: A Systems Engineering Approach" by Mohammad H. Sadraey). Reports and technical documents, studies published by specialized organizations and institutes (NASA Technical Reports Server; DARPA technical reports) were also considered. The systematization and analysis of existing studies and publications on the topic of robotics and unmanned aerial vehicle design allowed us to identify the main directions of development, key problems and achievements.

The research work used such methods of cognition of materials as analysis, synthesis, deduction and modeling [9, 10].

The aim is to conduct a functional-cost analysis of unmanned aerial vehicles and build a mathematical model of inter-industry interactions arising in the innovative production of high-precision and intelligent robots.

The object of the study is industrial enterprises of the defense-industrial complex of the

Russian Federation (hereinafter referred to as DIC). The subject of the study is intelligent robotics and innovative production of UAVs as representatives of dual-use goods and technologies of the Russian defense industrial complex [11, 12].

Robotics refers to the production of high-precision machines, they are produced by large machine-building enterprises in Russia. According to M.I. Baranov combat (military) robots are automatic devices that replace humans in combat situations to preserve human life or to work in conditions incompatible with human capabilities for military purposes (reconnaissance, combat operations, demining, etc.) [13]. The birth of intelligent robotics in the USSR began with the science of Cybernetics [11, 14].

Systems analysis methods: applying a systems approach to evaluate the interaction of components and components in a functional cost analysis of an unmanned aerial vehicle; evaluating the impact of changes in one part of the system on the overall performance and fair value of the product.

These contributions and methods will help structure a critical analysis of the literature on intelligent robotics and innovative drone engineering, providing a thorough understanding of the current state of the art and directions of this field of knowledge.

3 Results

Drones or unmanned aerial vehicles are being actively introduced in almost any sphere of activity and are a dual-use technology. Domestic scientists are actively engaged in developments both in the field of improving UAVs and for combating them. Table 1 (Compiled by the authors) presents a short patent overview of UAVs and their main characteristics.

Table 1. Patent overview of unmanned aerial vehicles.

Patent no.	Patent name	Patent authors and their owners	Main features
RU 2723203	Multi-purpose interceptor UAV	Agarkov A.V.	The invention relates to the field of aviation, in particular to designs of unmanned interceptors
RU 2653324	An unmanned aerial vehicle and its method of operation	Van-tor Jan, Stagliano Florian, Steinwandel Jürgen	The invention relates to the field of aviation, in particular to structures of large unmanned aerial vehicles
RU 2695015	Method of detection and defeat of low-observable combat mini- and micro-unmanned aerial vehicles	Kuznetsov N.S. NPO Delta JSC	The invention relates to the field of countering unmanned aerial vehicles (drones) and can be used in the development of complexes to combat them
RU 2765196 C2	Payload Aerodynamic Lift Unit (PLU)	Sidorov N.M., Borisov E.G., Kostrova E.I., Morozova E.V., Polkovnikov S.P. NII Vector JSC	The invention relates to the field of aviation, in particular to structures of unmanned aerial vehicles

From the data presented, it follows that scientists are engaged not only in unmanned aerial vehicles and modernize the structural part, but also find ways to combat and low-observable combat mini- and micro-UAVs. Small, lightweight, low-speed, and maneuverable UAVs such as multi-rotor platforms can incorporate many kinds of sensors that are suitable for

detecting objects of interest in cluttered open spaces. However, due to limited endurance, low computational power, and imperfect sensors, mini-UAVs must be clustered together using swarm coordination algorithms to accomplish tasks in a scalable, robust, and reliable manner.

From the specification of the product "multifunctional unmanned aerial vehicle" is created at the production enterprise, the material carrier of functions, then functional analysis, technological operations are carried out, materially responsible persons for each operation are appointed, a cyclogram (work execution plan-schedule) is drawn up, the product costing is presented. One of the civilian consumptions of information in the use of UAVs in the process of road design, construction and modernization allows for the efficient collection of data for such projects, as well as monitoring the construction process. In the construction industry, drones are used for advertising and marketing purposes. Photos of the project area can be used during the bidding stage. They are then used as a background for attractive architectural visualizations. Investors often commission photos and videos of completed projects and use these materials in marketing campaigns. Drone footage taken from inaccessible locations or from unusual angles attracts the attention of customers. For this reason, more and more drone footage are appearing online or on television.

The final cost of the finished dual-purpose product depends on the product costing. Accurate and up-to-date UAV cost information will enable companies to make informed decisions about pricing strategies, production volumes and resource allocation. With this valuable information, companies can determine the most cost-effective production methods, identify areas for cost reduction, and optimize their operations to improve profitability and competitiveness in the marketplace.

In addition, product costing plays an important role in budgeting, financial forecasting and assessing the financial viability of product lines or projects, giving businesses a complete picture of their financial health and assisting in long-term planning.

Let us represent the material carrier of UAV functions with respect to rank into three ABC groups in Table 2 (Compiled by the authors).

If the UAV is equipped with intelligent capabilities, the cost increases significantly. Nevertheless, intelligent robotics opens up huge opportunities for progress and improvement of the quality of life for defense industry production companies. It is important for Russia to develop this area of dual-use technologies responsibly, taking into account potential threats from the United States and European countries.

Let us present two alternative options for building a mathematical model of inter-sectoral interactions in the innovative production of high-precision and intelligent robots:

Option 1: to build a mathematical model of inter-industry interactions, in the innovative production of high-precision and intelligent robots, we can use the principles of inter-industry balance, which takes into account the interaction of different sectors of the economy. The manufacturing process of high-precision and intelligent robots involves several sectors of the economy, such as electronics manufacturing, mechanical engineering, programming, etc. Each industry has its inputs (resources) and outputs (finished products). Let us denote the variables in the model: X1, X2, ..., Xn - production flows in different sectors of the economy; A(ij) - coefficient of interaction between industries (i) and (j); Yi - final product produced in industry (i); Xi=∑(j)A(ij)Yj - production flows in industry (i), depending on the final product of all industries.

Taking these variables into account, it is possible to construct a system of equations describing the inter-industry interactions, in the production of high-precision and intelligent robots:

$$\begin{aligned} &[X1 = \sum(j)A(1j)Yj] \\ &[X2 = \sum(j)A(2j)Yj] \\ &\quad [\dots] \\ &[Xn = \sum(j)A(nj)Yj] \end{aligned} \qquad (1)$$

In addition, it is possible to include in the model such paramenters as: technological coefficients; innovation processes; research and development costs, etc.

Table 2. Material carrier for product functions.

Name of components	Component function	ABC ranking
Hull	Bearing and protective function of the product and its components	A
Main lift impeller	Creating a vertical thrust vector	A
Main propellers-propellers	A tool for expelling air at some additional velocity	A
Auxiliary propellers	A tool for expelling air at some additional velocity	B
Solid aerodynamic wing	A tool for creating aerodynamic force	B
Separate airfoil section	A tool for creating aerodynamic force	B
Main propeller motor	Converting energy into torque	A
Auxiliary propeller motor	Converting energy into torque	B
Power supply system	Accumulation and supply of energy to all consumers	A
Power supply cable retention bracket	Retention of the power supply cable	C
Supply cable	Power supply	C
Auxiliary battery charging control unit	Auxiliary battery recharge control	C
Wing section mechanization	Aerodynamic force vector control	B
Aerodynamic housing surface	Improved intake flow characteristics	C
Movable airfoil	Maneuvering in flight, providing emergency descent	B
Air blower	Creation of the flow directed on the moving aerodynamic wing	B
Shipping container	Protection for transportation	C
Antenna system	Providing in-flight communication with the command console	A
Shipping container flaps	Container protection	C
Mechanical elevator with take-off and landing platform	Automating the startup process	C
First (vertical) coaxial joint	Position control of air flow blowers and movable airfoil	B
Second (horizontal) coaxial joint	Position control of air flow blowers and movable airfoil	B

Variant 2: let us present a mathematical model of inter-industry interactions in the innovative production of dual-use goods and technologies. This model involves "N" industries and "M" innovative technologies. To take into account the processes of interaction in innovative production, we introduce the following variables: Xij - represents the volume of output produced by industry "i" using technology "j"; Yi - represents the total output of industry "i"; Zj - innovation resources required for the application of technology "j".

Then the mathematical model will include three components: production capabilities; innovation processes; and constraints. Let us consider them in detail:

Production capabilities of industrial enterprises for manufacturing robots:

$$[Yi = \sum(j = 1)\hat{}(M)X(ij)\quad\forall i = 1,2, \dots, N] \quad (2)$$

Innovation processes can be represented in the form of a formula:

$$[Zj = \sum(i = 1)\hat{}(N)X(ij)\quad\forall j = 1,2, \dots, M] \quad (3)$$

Constraints should be taken into account to ensure that the volume of output and innovation resources does not take a negative value:

$$[X(ij) \geq 0, Yi \geq 0, Zj \geq 0\quad\forall i, j\] \tag{4}$$

This model allows to determine the interrelationships between industries and innovative technologies in the production of dual-use goods and technologies. It takes into account both the needs of industries in innovation resources and their production capabilities, providing a basis for the analysis and optimization of innovation processes in various industrial sectors.

4 Discussion

Domestic and foreign scientists are actively considering the problems of implementing artificial intelligence in robotics. Studies of signal recognition features of small UAVs have been carried out, aspects of economic security of industrial enterprises have been studied [14]. Calculations on mobile objects and planning of innovative production of rotor-controlled systems in the Russian Federation are presented [15-18]. Prospects for the application of artificial intelligence in high-tech industrial enterprises of the Russian Federation are revealed [20, 21].

Intelligent robotics has great potential as a dual-use technology for solving various tasks and problems. Such sophisticated technical devices can significantly simplify and improve people's lives, as well as increase the efficiency of work in various fields. However, it should be noted that along with new opportunities, intelligent robotics also presents a number of challenges as the introduction of intelligent robots can cause job losses and lead to shifts in the economy. Currently, there has been an increase in the production of drones [22, 24]. In today's world, UAV production is becoming more and more relevant and in demand in the aviation industry. UAVs are widely used in various fields, from military use and reconnaissance to civil aviation, agronomy and environmental monitoring. Because of this, UAVs are considered a dual-use commodity and technology. The production of innovative UAVs requires modernization of core production business processes. The first step in modernization of the main business processes is automation of individual processes. This will reduce the time of manufacturing, assembly and testing of UAVs. The second important aspect of modernizing manufacturing business processes for UAV production is the application of the latest technologies and materials. Modern materials such as carbon fibers, composites and 3D printing make it possible to create lightweight, durable and cost-effective structures for UAVs. The use of advanced technologies in production allows us to reduce material costs and reduce the weight of the vehicles, which affects their maneuverability and flight range. The third important element of modernization of production business processes for UAV manufacturing is personnel training and renewal. The introduction of new technologies and production methods requires highly qualified specialists capable of working with modern equipment and software. Therefore, it is important to invest in professional training of personnel and create conditions for continuous support and development of the workforce.

However, with all the importance of the issue it is necessary to take into account the disadvantages of accelerated import substitution of dual-use goods and technologies, such as the modernization of the main production business processes requires significant investment in research and development, as well as the possibility of full and rapid replacement of imported spare parts and technologies.

5 Conclusion

The scientific article presents a view on the solution of the actual problem of uninterrupted production and development of intelligent robotics, including UAVs, which can be used as dual-use goods and technologies. A brief patent review of UAVs is presented and the basic characterization of the design idea is given. A functional-ranking analysis of UAVs is carried out and the material carrier of the product functions is presented. As a result, the following are formed:

- Drones and unmanned aerial vehicles have a number of advantages for both civilian and military use (small size and weight, maneuverability, quality of materials, human safety, accuracy, programmability, controllability, etc.).
- Drones have disadvantages (legislative and regulatory component, robustness of design, etc.).
- Drones and UAVs are representatives of dual-use goods and technologies and can be produced by machine-building enterprises both for the defense industry and for civilian use and consumption.
- Inter-industry links and interactions are formed in the production of UAVs, which makes it possible to create new jobs.

Further research will be related to promising modern technologies such as navigation systems, which are also dual-use goods and technologies that can be used for a variety of purposes.

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