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The Quality of Unmanned Aerial Vehicles: Ergo-Design Aspect

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Abstract
In the modern world, scientific and practical ergo-design activity on the development and use of drones, the concept of "human factor" is becoming more and more important. It is one of the main studies in improving the safety, efficiency and comfort of the "man - unmanned aerial vehicle" system operation. The most promising research is aimed at the application and development of new approaches to the evaluation of algorithms for unmanned aircraft maintenance and the organization of their operators` activities.

The system of unmanned aerial vehicles ergo-design quality indicators developed and presented in a tabular form reflects practically all design and ergonomic properties of modern unmanned aerial systems. It is based on the existing normative documentation in Ukraine developed by the authors, harmonized with international and European standards. It allows the analysis and evaluation of unmanned aerial vehicles in order to take into account consumer interests at the beginning of their design reducing the assimilation time of products and preventing irrational production costs.

The results of such an analysis underlie the development of technical documentation, standards, and specifications. They should be taken into account when putting products into production.

Keywords: unmanned aerial vehicle, ergo-design quality indicators, unmanned aircraft maintenance, operator activities, operational indicators, environmental awareness, versatility of UAV

1. INTRODUCTION

The intensification of activities aimed at the creation of unmanned aerial vehicles, which is taking place in the modern world and in recent years in Ukrainian practice, indicates the rapid development of this area as a means of solving many economic and military problems. In particular, there is considerable interest in the ergo-design problems of unmanned systems.

In the modern world, scientific and practical ergo-design activity on the development and use of drones, the concept of "human factor" connected with the introduction of new technologies in design and new approaches to UAVS application is becoming more and more important. It is one of the main studies in improving the safety, efficiency and comfort of the "man - unmanned aerial vehicle" system operation[1]. In particular, in recent years, more and more attention in the development of unmanned aerial vehicles has been paid to the problems of assessing the effectiveness and comfort of UAVS control systems, the remote piloting problems of individual aircraft and their groups. The most promising research is aimed at the application and development of autonomous artificial intelligence systems in the UAVS, which necessitates the formation of new approaches to the evaluation of algorithms for unmanned aircraft maintenance and the organization of their operators` activities. In general, most domestic and foreign researchers believe that the UAVS has the potential for modern aviation development. It determines the relevance of research in this area[2].

[1] Unmanned Aircraft Systems (UAS). Roadmap 2005-2030, Office of the Secretary of Defense; Hodson Ch. J., *Civil airworthiness for a UAV control station*, University of York, York 2008; Dali M., *Unmanned Aerial Vehicles and Targets, Jan´es Printed, Hobbs the Printers*, 2010, pp. 553-600; Papanek V., *Design for the real world. Human ecology and social change*, Academy Chicago Publishers, Chicago 2008, p. 416

[2] Dali M., *Unmanned Aerial Vehicles...*, pp. 553-600; Papanek V., *Design for the real world...*, p. 416; McCarley J. S., Wickens Ch. D., *Human factors concerns in UAV flight*,

The results of published research presented in monographs, scientific articles, textbooks, and regulations indicate the need for a qualitatively new methodology and measures for UAVS ergo-design assessment, development, and operation as well as the creation of relevant scientific and methodological documentation based on these findings.

In recent years, the authors of the publication in their research have laid the foundations of UAVS ergo-design in Ukraine, as evidenced by the manufactured and already functioning UAVS and developed ergo-design documentation, namely - national standards DSTU 7234, DSTU 7247, DSTU 7251, DSTU 7299, DSTU 7895, etc.[3]. To date, ergo-design aspects of the interaction of their components are studied; the dominant role of the human factor in the total number of aviation events with UAVs is proved, and, most importantly in terms of this publication, it is proved the need for ergo-design assessment of the human factor at the main stages of UAVS design and operation.

After all, solving the problems of evaluating UAVS operators` efficiency is the basis for optimizing the impact of the human factor.

Therefore, the creation of a multi-criteria qualitative and quantitative efficiency assessment system of UAVS design and operation on the criteria of ergonomics, safety, controllability, and comfort in their maintenance, etc., provides an opportunity to achieve a qualitatively new level of UAVS development saving costs. The development of UAVS ergo-design evaluation principles based on relevant requirements, indicators, the standardization of ergo-design quality indicators, and their evaluation methods also gives an opportunity to comprehensively and objectively consider the fundamental issues of UAVS ergo-design and standardize the ergo-design evaluation procedures of the existing and new UAVS.

[in:] *Aviation Human Factors Division University of Illinois at Urbana-Champaign. Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting, Institute of Aviation*, Human Factors and Ergonomics Society, Maryland 2002, pp. 2144-2148; Osipov Yu., *Requirements for tools and training programs for UAV operators in unmanned aircraft systems*, "Armament. Politics. Conversion", 99 (2011)/3.

[3] DSTU 7234:2011 Design and ergonomics. Production equipment. General requirements for design and ergonomics; DSTU 7247:2011 Design and ergonomics. Examination of the quality of industrial products. General provisions; DSTU 7251:2011 Design and ergonomics. Design and ergonomics requirements. Nomenclature and selection procedure; DSTU 7299:2013 Design and ergonomics. Operator's workstation. Relative position of workstation elements. General ergonomic requirements; DSTU 7895:2015 Design and ergonomics. Rules for assessing the ergonomic level of the quality of industrial products.

2. MATERIALS AND METHODS

The main methodological approach implemented in this publication is the formation of the processes of effective human interaction with technical means, which should be based on assessing the humanization level of human activity with objects around us, i.e. operators` interaction with the UAVS based on ergonomics and design principles. Under this approach, the ergo-design aspects of rationality, information value and safety of the environment, the creation of functional comfort are considered as dominant.

After all, taking into account a holistic set of issues related to the human factor in the "man - UAVS" systems developed by the authors in recent years is the main methodological basis for the formation of UAVS ergo-design quality indicators.

3. GENERAL DESCRIPTION OF THE SYSTEM OF ERGO-DESIGN INDICATORS

Contrary to popular belief, the result of ergo-design developments is not always a product (a machine, technical complex or environmental object), but their special properties. An ergo-design specialist never creates and cannot create them in a tangible embodiment. In the design process, they work with designers, technologists, and other professionals, and together they create a product design. At the stage of project materialization, interaction with production organizers, technologists, economists, and representatives of industrial workers, etc. is carried out. The ergo-design specialist is responsible for the formation of those properties of the designed product, system, or external entity, which are their professional prerogative, and for the consolidation of these properties into a single integral harmonious system.

Therefore, the ergo-design product is specifically qualimetric, i.e. focused on achieving a certain quality. This quality is informationally enshrined in the project and potentially "ready for consumption (use)" through the object, system or external entity. Hence, a prerequisite for design efficiency is a deep knowledge of the user's values by the designer. Based on a clear idea of desires and requirements, it becomes possible to take into account all consumer, ergo-design and production requirements, which, in turn, should ensure the appropriate properties of the designed product, system or external entity.

Consumer attributes are characterized by specific ergo-design parameters, namely: ergo-design indicators of the object (or requirements for it at the stages of concept formulation and design). These parameters determine the real usefulness, the operation of the product, and its quality after the project implementation. Thus, in the chain of the "requirements – properties – indicators" system, "indicators" is the final step, which characterizes the achieved product quality level. It should be noted that the indicator is a qualimetric manifestation of the requirement and as long as the indicator is not characterized by the value, its definition coincides with the definition of the requirement. It follows that the detailed set of ergo-design requirements for the main UAVS components, which are specified[4], can reasonably be used as expanded nomenclatures of ergo-design indicators of the relevant UAVS components

Let us recall the methodological principles according to which the detailed nomenclatures of ergo-design requirements are established[5].

1. To determine the ergo-design requirements (indicators) for the UAVS ergo--design requirements (indicators) to each of the system components were determined.
2. Expanded nomenclatures were established in accordance with the requirements of the national standards of Ukraine, in particular developed by the authors of the article: DSTU 3963 and DSTU 4055-2001[6].
3. The widest possible range of indicators from the standard nomenclatures included in the specified standards was added to the established nomenclatures, only those indicators the compliance with which is beyond dispute have been removed. Conversely, in case compliance with an indicator is open to question, the indicator is included in the relevant nomenclature.

[4] Kharchenko V., Rubtsov A., Svirko V., *Ergo-design Factor in the Development of Unmanned Aircraft Systems,* "Proceedings of the National Aviation University", 81 (2019)/4, pp. 6-13; Rubtsov A, Svirko V, Matiichik M., Kharchenko V, Shmelova T., *Methodology of ergo-design assessment of unmanned aircraft complexes,* UkrNDI DE, Kiev 2021, p. 219.

[5] Kharchenko V., Rubtsov A., Svirko V., *Ergo-design Factor in the Development...*, pp. 6-13; Rubtsov A, Svirko V, Matiichik M., Kharchenko V, Shmelova T., *Methodology of ergo-design...*, p. 219.

[6] DSTU 3963-2000 Design and ergonomics. Classification and nomenclature of design and ergonomic quality indicators of household devices and appliances; DSTU 4055-2001 Design and ergonomics. Nomenclature of design and ergonomic product quality indicators for industrial and technical purposes.

4. Exclusion of indicators from the standard nomenclature was carried out taking into account the opinions of the expert group, expressed through estimates from 0 to 5. Analysis and evaluation of indicators were carried out by a group of experts in accordance with the requirements developed by the authors of DSTU 7234, DSTU 7298, DSTU 7895, DSTU 7896[7]. Indicators that received a generalized score of less than 2.5 on a five-point scale were removed. The obtained nomenclature (defined as optimized) underlay the development of detailed nomenclatures of ergo-design requirements for each of the UAVS components

4. DETERMINATION OF EXPANDED NOMENCLATURES OF ERGO-DESIGN QUALITY INDICATORS OF THE MAIN UAVS COMPONENTS

To optimize the process of applying indicators, each of them was given its own code, consisting of one letter and four digits. This code is specified in brackets after the name of each indicator. The first designation in the code is one of the main UAVS components:

- unmanned aerial vehicle (UAV) - U;
- ground control station (GCS) - G;
- starting device (SD) - S;
- landing aid (LA) - L;
- antenna and rotary device (ARD) - A.

Applying the standardized typical nomenclature of ergo-design quality indicators regulated by DSTU 3963 and DSTU 4055 (see note 2), we define the following digits of the code: the second - for group (ergonomic - 1, aesthetic - 2, functional - 3, operational - 4, social and cultural - 5, design and marketing - 6, design and environmental - 7), the third - for complex indicators of the 1st level, the fourth - for complex quality indicators of the 2nd level (see table 2.1).

[7] DSTU 7298:2013 Design and ergonomics. Rules for assessing the aesthetic quality level of industrial products; DSTU 7896:2015 Design and ergonomics. Rules for assessing the functional quality level of industrial products

Table 2.1. Expanded nomenclature of ergo-design quality indicators with the definition of three further designations (digits) of the code

Group of UAVS indicators, the second digit of the code	Complex UAVS indicator of the 1st level, the second and third digits of the code	Complex UAVS indicator of 2nd level, the second, third and fourth digits of the code
Ergonomic indicators **(1)**	Ease of use of the product for its intended purpose **(1.1)**	Ergonomics of design and layout of the operator's workstation **(1.1.1)**
		Correspondence of a product design, its elements to the anthropometric characteristics of the human **(1.1.2)**
		The operator`s physical load (severity of work performed) **(1.1.3)**
		The operator`s psychophysiological load (work intensity) **(1.1.4)**
		Development of fatigue and a reduction in the operator`s functional state for a given time **(1.1.5)**
	Ease of management and control (controllability) **(1.2)**	Ergonomics of the form, sizes, an arrangement of control panels and dashboards **(1.2.1)**
		Ease of perception of the displayed information **(1.2.2)**
		Ergonomics of visual information display devices **(1.2.3)**
		Ergonomics of acoustic information **(1.2.4)**
		Ergonomics of tactile information **(1.2.5)**
		Convenience of product controls design **(1.2.6)**
		Ergonomic placement of controls **(1.2.7)**
		Rationality of product layout **(1.2.8)**
	Product assimilation **(1.3)**	Information model quality **(1.3.1)**
		Completeness and convenience of the product operation manual **(1.3.2)**
	Product maintenance **(1.4)**	–
		Ergonomics of operational documentation **(1.4.2)**
		Ergonomics of equipment and tools required for product operation **(1.4.3)**
	Hygiene of the product and the working area environment **(1.5)**	Product physical factors and the working area environment **(1.5.1)**
		Chemical factors of the product and the working area environment **(1.5.2)**
		Biological factors of the product and the working area environment **(1.5.3)**

Aesthetic indicators **(2)**	Artistic expression **(2.1)**	Graphic expression **(2.1.1)**
Functional indicators **(3)**	Rationality of the form **(2.2)**	Originality **(2.1.2)**
		Fashionableness **(2.1.3)**
		Decorative expression **(2.1.4)**
		Stylistic unity **(2.1.5)**
		Functional and constructive conditionality of the form **(2.2.1)**
	Integrity of a compositional-plastic form solution **(2.3)**	Technological conditionality of the form **(2.2.2)**
		Harmony of three-dimensional structure **(2.3.1)**
	Perfection of production and the preservation of a marketable condition **(2.4)**	Architectonic form **(2.3.2)**
		Plasticity of the form **(2.3.3)**
		Artistic and graphic expression **(2.3.4)**
		Colour and graphic compatibility of elements **(2.3.5)**
		Colour and texture compatibility of elements **(2.3.6)**
		Fineness of contours **(2.4.1)**
	Perfection of the main function performance **(3.1)**	Quality of surface treatment **(2.4.2)**
		Clarity of signs and accompanying documentation **(2.4.3)**
		Resistance to damage **(2.4.4)**
		Efficiency of UAV use **(3.1.1)**
Operational indicators **(4)**	Versatility of use **(3.2)**	The range of UAV use for its intended purpose **(3.2.1)**
	Perfection of auxiliary operations **(3.3)**	Perfection of preparatory operations **(3.3.1)**
	Ease of product operation **(4.1)**	Perfection of final operations **(3.3.2)**
		–
	Ease of product maintenance **(4.2)**	–
	Reliability **(4.3)**	Failure-free operation **(4.3.1)**
		Durability **(4.3.2)**
		Maintainability **(4.3.3)**

Social cultural indicators **(5)**	Social address and consumer class of the product **(5.1)**	–
	Compliance with the optimal nomenclature **(5.2)**	–
	Moral aging **(5.3)**	–
Design and marketing indicators **(6)**	The degree of compliance with the world level **(6.1)**	–
	Compliance with the requirements of the potential target market **(6.2)**	–
Design and environmental indicators **(7)**	The nature and extent of the impact on the environment **(7.1)**	–
	The degree of resource-preservation **(7.2)**	–
	Utilization degree of product materials **(7.3)**	–
	Utilization rate of recycled materials and product components **(7.4)**	–
	Compliance with the requirements of environmental awareness training **(7.5)**	–

Thus, the first four indicators (a letter and three digits) of the code of ergo-design quality indicators are set. The last fifth figure represents a single indicator. They are not general in nature and depend on a specific product. Therefore, they were applied to each UAVS component separately.

So, let's define the expanded nomenclature of ergo-design quality indicators of the main UAVS components.

4.1 Expanded nomenclature of UAV ergo-design quality indicators

Ergonomic UAV quality indicators are given in table 2.2.

Table 2.2. Expanded nomenclature of UAV ergo-design quality indicators. Ergonomic indicators (U.1)

COMPLEX INDICATOR OF LEVEL 1: **Ease of UAV use for its intended purpose** (U.1.1)	
Complex indicator of the 2nd level	Single indicator
Correspondence of a UAV design, its elements to the anthropometric characteristics of the human (U.1.1.2)	Taking into account the size of the human body and its parts in the size of the UAV structural elements (U.1.1.2.1)
The operator`s physical load (severity of work performed) (U.1.1.3)	Dynamic physical activity (volume of work performed during transportation, preparation for use, configuration, adjustment, UAV assembly(disassembly); weight of transported cargo) (U.1.1.3.1) Static physical activity (effort to hold a UAV during take-off) (U.1.1.3.2)
COMPLEX INDICATOR OF LEVEL 1: **UAV assimilation** (U.1.3)	
Completeness and convenience of UAV operation manual (U.1.3.2)	Level of completeness of the UAV operation manual (U.1.3.2.1) Clarity of the manual (U.1.3.2.2) Quality of material formatting (U.1.3.2.3)
COMPLEX INDICATOR OF LEVEL 1: **UAV maintenance (**U.1.4)	
– (U.1.4.0)	Promptness of maintenance, repair, and preparation for flight (U.1.4.0.1) Complexity of the maintenance and repair algorithm (U.1.4.0.2) Ease of access to adjustable and replaceable elements (U.1.4.0.3) Availability of technical means for diagnosing faults and convenience of troubleshooting (U.1.4.0.4) Quality of technical documentation (U.1.4.0.5)
Ergonomics of UAV operation documentation (U.1.4.2)	Completeness of UAV operation documentation (U.1.4.2.1) Convenience of material presentation structure, levels of information decoding and re-coding (U.1.4.2.2) Quality of illustrations, schemes, graphic elements, documentation format Documentation storage capability (U.1.4.2.3)

Ergonomics of equipment and tools required for the UAV operation (U.1.4.3)	Ease of use of control, measuring, and testing equipment (U.1.4.3.1) Compliance of lighting equipment with the specified norms of general and local lighting (U.1.4.3.2) Convenience and safety of use of the tool during carrying out works in the given conditions (in hard-to-reach places, in the conditions of an overload) (U.1.4.3.3)
COMPLEX INDICATOR OF LEVEL 1: **UAV hygiene** (U.1.5)	
UAV physical factors (U.1.5.1)	Noise levels (U.1.5.1.1) Vibration levels (U.1.5.1.2)
UAV chemical factors (U.1.5.2)	Presence of harmful components in fuel, UAV materials and coatings (U.1.5.2.1)
COMPLEX INDICATOR OF LEVEL 1: UAV safety (U.1.6)	
– (U.1.6.0)	Safety level of the factors of mechanical origin (U.1.6.0.1) Safety level of the influence of electric current (U.1.6.0.2) Safety level due to the product operation algorithm (U.1.6.0.3)

UAV aesthetic quality indicators are given in table 2.3.

Table 2.3. Expanded nomenclature of UAV ergo-design quality indicators. Aesthetic indicators (U.2)

COMPLEX INDICATOR OF LEVEL 1: **UAV artistic expression** (U.2.1)	
Complex indicator of the 2nd level	Single indicator
UAV image expression (U.2.1.1)	Correspondence of the UAV image to its intended use. (U.2.1.1.1) Correspondence of the UAV image to modern ideas about products of a certain type (U.2.1.1.2)
UAV form originality (U.2.1.2)	Peculiarity of the used UAV formation principles: plastic (U.2.1.2.1), compositional (U.2.1.2.2), layout (U.2.1.2.3) Peculiarity of UAV decorative and colour elements (U.2.1.2.4) Correspondence of UAV originality methods to the requirements of expediency (U.2.1.2.5)
Fashionableness (U.2.1.3)	Correspondence of the colour and graphic solution, UAV finishing to "fashionable" decorating methods (U.2.1.3.1) Correspondence of UAV compositional and plastic characteristics to "fashionable" methods of form making (U.2.1.3.2)

Decorative expression of the UAV form (U.2.1.4)	Decorative expression of the used materials and coverings (U.2.1.4.1) Correspondence of the UAV decorative expression methods to the requirements of expediency (U.2.1.4.2)
COMPLEX INDICATOR OF LEVEL 1: **Rationality of the UAV form** (U.2.2)	
Functional and constructive conditionality of the form (U.2.2.1)	Compliance of the UAV form with the purpose and operating conditions (U.2.2.1.1) Correspondence of the UAV form to its composition and layout (U.2.2.1.2) Suitability of the use of constructive methods of organizing the UAV form elements (U.2.2.1.3)
Technological conditionality of the UAV form (U.2.2.2)	Correspondence of the UAV form to the requirements of its manufacturing technology (U.2.2.2.1)
COMPLEX INDICATOR OF LEVEL 1: **Integrity of the UAV compositional-plastic form solution** (U.2.3)	
Harmony of the UAV three-dimensional structure (U.2.3.1)	Interdependence of primary and secondary elements of the UAV form in size, proportions and scale (U.2.3.1.1) The degree of UAV scale and its elements (visual correspondence to the size of the human body) (U.2.3.1.2)
UAV architectonic form (U.2.3.2)	Manifestation in the form of its structural nature loads (U.2.3.2.1) Visual balance of the UAV three-dimensional, compositional and plastic structure (U.2.3.2.2)
Plasticity of the UAV form (U.2.3.3)	Integrity of three-dimensional and plastic solution of the UAV form (U.2.3.3.1) Correspondence of the volumetric and plastic solution to applied materials, and manufacturing technology (U.2.3.3.2)
COMPLEX INDICATOR OF LEVEL 1: **Integrity of the UAV compositional-plastic form solution** (U.2.3)	
Artistic and graphic expression (U.2.3.4)	Compositional validity of the arrangement of graphic elements on the UAV parts (U.2.3.4.1) The degree of conformity of the nature of the fonts to the semantic value of the inscriptions (U.2.3.4.2) Expression of functional graphics (U.2.3.4.3)
Colour and graphic compatibility of elements (U.2.3.5)	Interdependence between colour and graphic elements (U.2.3.5.1) Subordination of colour and graphic elements to the general UAV compositional and colour and graphic solution (U.2.3.5.2)

Colour and texture compatibility of elements (U.2.3.6)	Compatibility of different types of materials, composition, textures, coatings used in the UAV with each other (U.2.3.6.1) Consistency of different types of materials, composition, textures, coatings with the UAV shape, purpose, and operating conditions (U.2.3.6.2)
COMPLEX INDICATOR OF LEVEL 1: **Perfection of production and the preservation of a marketable condition** (1.2.4)	
Fineness of contours (U.2.4.1)	Fineness of contours, fillets, and joints of the elements of the UAV fuselage, wings, and other structural components (U.2.4.1.1)
Quality of the UAV surface treatment (U.2.4.2)	Careful treatment of UAV surfaces (U.2.4.2.1) Careful application of decorative and protective coatings (U.2.4.2.2)
Clarity of signs and accompanying documentation (U.2.4.3)	Quality of UAV graphic elements, PDT, and promotional materials to it (U.2.4.3.1)
Resistance to damage (U.2.4.4)	Protection of the UAV form elements and surfaces against damage, attrition, and decorative covering quality changes (U.2.4.4.1)

UAV functional quality indicators are given in table 2.4

Table 2.4. Expanded nomenclature of UAV ergo-design quality indicators. Functional indicators (U.3)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of the main UAV function performance** (U.3.1)	
Complex indicator of the 2nd level	Single indicator
Efficiency of UAV use (U.3.1.1)	The degree of satisfaction with the UAV during its intended use (U.3.1.1.1)
COMPLEX INDICATOR OF LEVEL 1: **Versatility of UAV use** (U.3.2)	
The range of UAV use for its intended purpose (U.3.2.1)	The range of UAV conditions and capabilities for various use, as well as the availability of additional functions useful for the consumer which are related to the main (U.3.2.1.1)
COMPLEX INDICATOR OF LEVEL 1: **Perfection of auxiliary operations** (U.3.3)	
Perfection of preparatory operations (U.3.3.1)	Suitability of the UAV to perform auxiliary transportation operations and preparation for launch (U.3.3.1.1)

Perfection of final operations (U.3.3.2)	Suitability of the UAV to perform auxiliary operations of disassembly, cleaning, packaging and transportation (U.3.3.2.1)

UAV operational quality indicators are given in table 2.5.

Table 2.5. Expanded nomenclature of UAV ergo-design quality indicators Operational indicators (U.4)

COMPLEX INDICATOR OF LEVEL 1: **Ease of product operation (U.4.1)**	
Complex indicator of the 2nd level	Single indicator
– (U.4.1.0)	Perfection of the UAV use during service operations accompanying implementation of the main and additional functions (U.4.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: Ease of product maintenance (U.4.2)	
– (U.4.2.0)	Perfection of preparatory and final operations, and also UAV regulation in the course of operation (U.4.2.0.1) UAV suitability to perform auxiliary operations of maintenance, storage, and disposal (U.4.2.0.2)
COMPLEX INDICATOR OF LEVEL 1: **UAV reliability (U.4.3)**	
UAV failure-free operation (U.4.3.1)	Preservation of the basic parameters of UAV operation in time and within the limits corresponding to the set operating conditions (U.4.3.1.1)
UAV durability (U.4.3.2)	Preservation of the basic parameters of UAV operation before the limit state is achieved at which their fulfilment becomes impossible. (U.4.3.2.1)
UAV maintainability (U.4.3.3)	Possibility of urgent UAV repair in field conditions (U.4.3.3.1) The average duration and complexity of the current UAV repair in stationary conditions (U.4.3.3.2)

Socio-cultural UAV quality indicators are given in table 2.6.

Table 2.6. Expanded nomenclature of UAV ergo-design quality indicators. Socio-cultural indicators (U.5)

COMPLEX INDICATOR OF LEVEL 1: **UAV social address and consumer class (U.5.1)**	
Complex indicator of the 2nd level	Single indicator
– (U.5.1.0)	Correspondence of the UAV to the structure of needs of a certain target audience (U.5.1.0.1)

COMPLEX INDICATOR OF LEVEL 1: **Compliance with the optimal UAV nomenclature (U.5.2)**	
– (U.5.2.0)	Efficiency of UAV use in the operational or projected UAV system of a certain type (U.5.2.0.1)
COMPLEX INDICATOR OF LEVEL 1: **UAV moral aging (U.5.3)**	
– (U.5.3.0)	The UAV service life is limited by the introduction of new drones of higher quality, as well as changes in social norms, cultural and value orientations (U.5.3.0.1)

Design and marketing indicators of the UAV quality are given in table 2.7.

Table 2.7. Expanded nomenclature of UAV ergo-design quality indicators. Design and marketing indicators (U.6)

COMPLEX INDICATOR OF LEVEL 1: **The degree of UAV compliance with the world level (U.6.1)**	
Complex indicator of the 2nd level	Single indicator
– (U.6.1.0)	The level of UAV design and ergonomic characteristics in comparison with the products of the leading manufacturers of similar products (U.6.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Compliance with the requirements of the potential target market (U.6.2)**	
– (U.6.2.0)	The degree of market demand for a particular UAV (U.6.2.0.1)

UAV design and environmental quality indicators are given in table 2.8.

Table 2.8. Expanded nomenclature of UAV ergo-design quality indicators. Design and environmental indicators (U.7)

COMPLEX INDICATOR OF LEVEL 1: **The nature and extent of the UAV impact on the environment (U.7.1)**	
Complex indicator of the 2nd level	Single indicator
– (U.7.1.0)	The impact of UAV on the environment during its life cycle (U.7.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Utilization degree of UAV materials (U.7.3)**	
– (U.7.3.0)	The output of recycled materials (U.7.3.0.1)

4.2 Expanded nomenclature of the ergo-design quality indicators of ground control stations

Let us define GCS ergo-design quality indicators (see Figure 2.1, 2.2). It should be borne in mind that the general requirements for control centres are set in a series of standards DSTU ISO 11064 "Ergonomic design of control centres[8], and the rules for assessing the quality of automated workstations (according to the indicators specified there) - in DSTU 8603:2015[9]. Therefore, the development and evaluation of the mobile and stationary GCS should be performed in accordance with the requirements and indicators of the above standards.

Figure 2.1. Manual UAV GCS, Source http://war4eternity.blogspot.com/2015/04/

Based on this, we will develop a nomenclature of ergo-design quality indicators of the manual and portable GCS, which are not covered by these standards.

[8] ISO 11064-1:2000 Ergonomic design of control centres, Part 1: Principles for the design of control centres; ISO 11064-2:2000 Ergonomic design of control centres, Part 2: Principles for the arrangement of control suites; ISO 11064-3:1999 Ergonomic design of control centres, Part 3: Control room layout; ISO 11064-4:2013 Ergonomic design of control centres, Part 4: Layout and dimensions of workstations; ISO 11064-5:2008 Ergonomic design of control centres, Part 5: Displays and controls; ISO 11064-6:2005 Ergonomic design of control centres, Part 6: Environmental requirements for control centres.

[9] DSTU 8603 (Design and ergonomics. Rules for assessing the quality level of automated workstations).

The expanded nomenclature of GCS ergo-design quality indicators is given in tables 2.9–2.15

Figure 2.2. Portable GCS,
Source http://www.kvand-is.com/produktsiya/portativnaya-stantsiya-kontrolya-i-upravleniya

GCS ergonomic quality indicators are given in table 2.9.

Table 2.9. Expanded nomenclature of GCS ergo-design quality indicators. Ergonomic indicators (G.1)

COMPLEX INDICATOR OF LEVEL 1: **Ease of use of the GCS for its intended purpose** (G.1.1)	
Complex indicator of the 2nd level	Single indicator
Correspondence of GCS design, its elements to the anthropometric characteristics of the human (G.1.1.2)	Taking into account in the GCS design the size of the human body and its parts (G.1.1.2.1) Taking into account in the GCS design the form of the human body and its parts (G.1.1.2.2)
COMPLEX INDICATOR OF LEVEL 1: **Ease of use of the GCS for its intended purpose** (G.1.1)	
Complex indicator of the 2nd level	Single indicator

The operator`s physical load (severity of work performed) (G.1.1.3)	Dynamic physical activity: the amount of work performed during the transportation of GCS, preparation for use, of configuration, adjustment, assembly (disassembly); the mass of the GCS during movement (G.1.1.3.1) Static physical activity (holding effort) (G.1.1.3.2) Deviation of working posture and movements from physiologically rational characteristics (G.1.1.3.3)
The operator`s psychophysiological load (work intensity) (G.1.1.4)	The level of monotony of the operator`s activity (G.1.1.4.1) Information load of the operator (G.1.1.4.2) Intellectual intensity of the operator` s activity (G.1.1.4.3) Nervous and mental and emotional tension of the operator s activity (G.1.1.4.4)
Development of fatigue and a reduction in the operator`s functional state for a given time (G.1.1.5)	The operator's energy consumption level (G.1.1.5.1) The level of changes in the operator`s functional state (G.1.1.5.2) The level of reduction of the emotional background (G.1.1.5.3) The level of work motivation reduction (G.1.1.5.4)
COMPLEX INDICATOR OF LEVEL 1: **Ease of management and control (controllability)** (G.1.2)	
Ergonomics of the form, sizes, an arrangement of GCS control panels (G.1.2.1)	Correspondence of the form of control panels to the algorithm of GCS service (G.1.2.1.1) Correspondence of the sizes of control panels to the algorithm of GCS service (G.1.2.1.2) Correspondence of mutual arrangement of control panels to the algorithm of GCS service (G.1.2.1.3) Correspondence of viewing angles of GCS control panels to the anthropometric and psychophysiological characteristics of the operator (taking into account the degree of importance and frequency of their use) (G.1.2.1.4)
Ease of perception of the displayed information (G.1.2.2)	The levels of direct and inverse contrasts (G.1.2.2.1) The coefficient of uneven brightness of information elements (G.1.2.2.2) The unevenness of the brightness characteristic of the screen field (G.1.2.2.3) Linear values of image distortion in the screen area (G.1.2.2.4)
COMPLEX INDICATOR OF LEVEL 1: **Ease of management and control (controllability)** (G.1.2)	

Ergonomics of visual information display devices (G.1.2.3)	Correspondence of the external lightning of signs, signals, and inscriptions to the ergonomic requirements (G.1.2.3.1) Compliance of information coding methods with ergonomic requirements (G.1.2.3.2) Conformity of the sizes of signs, signals, and inscriptions to the ergonomic requirements (G.1.2.3.3) Correspondence of a configuration of signs, signals, and inscriptions to the ergonomic requirements (G.1.2.3.4) Correspondence of viewing angles of signs, signals, and inscriptions to the ergonomic requirements (G.1.2.3.5)
COMPLEX INDICATOR OF LEVEL 1: **Ease of management and control (controllability)** (G.1.2)	
Complex indicator of the 2nd level	Single indicator
Ergonomics of acoustic information (G.1.2.4)	Correspondence of message types to the GCS operation algorithm (a bell, buzzer, siren, musical tone or speech) (G.1.2.4.1) Correspondence of the nature of messages to the GCS operation algorithm (simple, complex, periodic, and continuous with disconnection during response time) (G.1.2.4.2)
Ergonomics of tactile information means (G.1.2.5)	Conformity of the means of information provision to the GCS operation algorithm (vibration, configuration, temperature, and amperage) (G.1.2.5.1) Compliance of levels of electrical, chemical, and thermal signals with the ergonomic requirements (G.1.2.5.2)
Convenience of product controls design (G.1.2.6)	Conformity of the form and the constructive execution of control bodies to ergonomic requirements (G.1.2.6.1) Conformity of the sizes of control bodies to the ergonomic requirements (G.1.2.6.2) Correspondence between the effort required to bring the controls in action and the ergonomic requirements (G.1.2.6.3)
Ergonomic placement of controls (G.1.2.7)	Correspondence of the nature of the operator's control movements to the functional state of the controlled system (G.1.2.7.1) Conformity of the combination methods of several control bodies to the ergonomic requirements (G.1.2.7.2) Correspondence of distance to controls (taking into account the degree of importance and frequency of their use) with the operator`s anthropometric characteristics (G.1.2.7.3) Availability and adequacy of the protection means for controls (G.1.2.7.4)

Rationality of GCS layout (G.1.2.8)	Compliance of GCS sizes with the ergonomic requirements (G.1.2.8.1) Optimal placement of information display means and controls (G.1.2.8.2)
COMPLEX INDICATOR OF LEVEL 1: **GCS assimilation** (G.1.3)	
Information model quality (G.1.3.1)	Adequacy of the information model (G.1.3.1.1) Stereotypes of the information model (G.1.3.1.2) Adequacy of information on the product and process (G.1.3.1.3) Redundancy of product and process information (G.1.3.1.4) Structural ordering of the information model (G.1.3.1.5)
Completeness and convenience of GCS operation manual (G.1.3.2)	The level of completeness of the operating manual (G.1.3.2.1) Clarity of the instructions (G.1.3.2.2) Quality of material design (G.1.3.2.3)
COMPLEX INDICATOR OF LEVEL 1: **GCS maintenance** (G.1.4)	
– (G.1.4.0)	Comfort and the rate of maintenance, repair, preparation for operation (G.1.4.0.1) The complexity of the maintenance and repair algorithm (G.1.4.0.2) Ease of access to adjustable and replaceable elements (G.1.4.0.3) Availability of technical means for diagnosing faults (G.1.4.0.4)
Complex indicator of the 2nd level	Single indicator
Ergonomics of operational documentation (G.1.4.2)	Completeness of operational documentation (G.1.4.2.1) Convenience of the material presentation structure, the levels of information decoding and re-coding (G.1.4.2.2) Quality of illustrations, schemes, graphic elements, and documentation format (G.1.4.2.3) Documentation storage capability (G.1.4.2.4)
Ergonomics of equipment and tools required for the GCS operation (G.1.4.3)	Ease of use of control, measuring, and testing equipment (G.1.4.3.1) Compliance of lighting equipment with the specified norms of general and local lighting (G.1.4.3.2) Convenience and safety of use of the tool during carrying out works in the given conditions (especially in the field environment) (G.1.4.3.3)
COMPLEX INDICATOR OF LEVEL 1: **GCS hygiene** (G.1.5)	
Physical factors (G.1.5.1)	Indicators of the level of illumination of work surfaces and controls (G.1.5.1.1)
Chemical factors (G.1.5.2)	Presence of harmful components in materials and coatings (G.1.5.2.1)

COMPLEX INDICATOR OF LEVEL 1: **GCS safety** (G.1.6)	
– (G.1.6.0)	Safety level of the factors of mechanical origin (G.1.6.0.1) Safety level of the factors of chemical origin (G.1.6.0.2) Safety level of the influence of an electric current (G. 1.6.0.3) Safety level due to the completeness of taking into account of the psychophysiological characteristics of the consumer (G.1.6.0.4) The level of safety due to the algorithm of the GCS operation (G.1.6.0.5)

GCS aesthetic quality indicators are given in table 2.10.

Table 2.10. Expanded nomenclature of GCS ergo-design quality indicators. Aesthetic indicators (G.2)

COMPLEX INDICATOR OF LEVEL 1: **UAV artistic expression** (G.2.1)	
Complex indicator of the 2nd level	Single indicator
GCS image expression (G.2.1.1)	Correspondence of the GCS image to its intended use. (G.2.1.1.1) Correspondence of the GCS image to modern ideas about products of a certain type (G.2.1.1.2)
GCS form originality (G.2.1.2)	Peculiarity of the used GCS formation principles: plastic (G.2.1.2.1), compositional (G.2.1.2.2), layout (G.2.1.2.3) Peculiarity of GCS decorative and colour and graphic elements (G.2.1.2.4) Correspondence of GCS originality methods to the requirements of expediency (G.2.1.2.5)
COMPLEX INDICATOR OF LEVEL 1: **UAV artistic expression** (G.2.1)	
Complex indicator of the 2nd level	Single indicator
GCS form fashionableness (G.2.1.3)	Correspondence of the colour and graphic solution, GCS finishing to "fashionable" decorating methods (G.2.1.3.1) Correspondence of GCS compositional and plastic characteristics to "fashionable" methods of form making (G.2.1.3.2)
Decorative expression of the GCS form (G.2.1.4)	Decorative expression of the used materials and coverings (G.2.1.4.1) Correspondence of the GCS decorative expression methods to the requirements of expediency (G.2.1.4.2)
GCS stylistic unity of the form (G.2.1.5)	Correspondence of GCS design features to each other within the limits of the chosen style (level of eclecticism) (G.2.1.5.1) Correspondence of GCS design features to other components of a complex within the limits of the chosen style (G.2.1.5.2)

COMPLEX INDICATOR OF LEVEL 1: **Rationality of the GCS form** (G. 2.2)	
Functional and constructive conditionality of the GCS form (G.2.2.1)	Compliance of the GCS form with the purpose and operating conditions (for example, manual and portable GCS) (G.2.2.1.1) Correspondence of the GCS form to its composition and layout (G.2.2.1.2) Suitability of the use of constructive methods of organizing the GCS form elements (G.2.2.1.3)
Technological conditionality of the GCS form (G.2.2.2)	Correspondence of the GCS form to the requirements of its manufacturing technology (G.2.2.2.1)
COMPLEX INDICATOR OF LEVEL 1: **Integrity of the GCS compositional-plastic form solution** (G. 2.3)	
Harmony of the GCS three-dimensional structure (G.2.3.1)	Interdependence of primary and secondary elements of the GCS form in size, proportions and scale (G.2.3.1.1) The degree of GCS scale and its elements (visual correspondence to the size of the human body) (G.2.3.1.2)
GCS architectonic form (G.2.3.2)	Manifestation in the form of its structural nature loads (G.2.3.2.1) Visual balance of the GCS three-dimensional, compositional and plastic structure (G.2.3.2.2)
Plasticity of the GCS form (G.2.3.3)	Integrity of three-dimensional and plastic solution of the GCS form (G.2.3.3.1) Correspondence of the volumetric and plastic solution to applied materials, and manufacturing technology (G.2.3.3.2)
Artistic and graphic expression (G.2.3.4)	Compositional validity of the arrangement of graphic elements on the GCS parts (G.2.3.4.1) The degree of conformity of the nature of the fonts to the semantic value of the inscriptions (G.2.3.4.2) Expression of functional graphics (G.2.3.4.3)
Colour and graphic compatibility of elements (G.2.3.5)	Interdependence between colour and graphic elements (G.2.3.5.1) Subordination of colour and graphic elements to the general GCS compositional and colour and graphic solution (G.2.3.5.2)
COMPLEX INDICATOR OF LEVEL 1: **Integrity of the GCS compositional-plastic form solution** (G. 2.3)	
Complex indicator of the 2nd level	Single indicator
Colour and texture compatibility of elements (G.2.3.6)	Compatibility of different types of materials, composition, textures, coatings used in the GCS with each other (G.2.3.6.1) Consistency of different types of materials, composition, textures, coatings with the GCS shape, purpose, and operating conditions (G.2.3.6.2)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of production and the preservation of a marketable condition** (G.2.4)	
Fineness of contours (G.2.4.1)	Fineness of contours, fillets, and joints of the elements of the GCS form (G.2.4.1.1)
Quality of the GCS surface treatment (G.2.4.2)	Careful treatment of GCS surfaces (G.2.4.2.1) Careful application of decorative and protective coatings (G.2.4.2.2)
Clarity of signs and accompanying documentation (G.2.4.3)	Quality of UAV graphic elements, PDT, and promotional materials to (G.2.4.3.1)
Resistance to damage (G.2.4.4)	Protection of the GCS form elements and surfaces against damage, attrition, and decorative covering quality changes (G.2.4.4.1)

Functional GCS quality indicators are given in table 2.11.

Table 2.11. Expanded nomenclature of GCS ergo-design quality indicators. Functional indicators (G.3)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of the main GCS function performance** (G.3.1)	
Complex indicator of the 2nd level	Single indicator
Efficiency of GCS use (G.3.1.1)	The degree of satisfaction with the control function in the UAV flight (G.3.1.1.1)
COMPLEX INDICATOR OF LEVEL 1: **Versatility of GCS use** (G.3.2)	
The range of GCS use for its intended purpose (G.3.2.1)	The range of UAV conditions and capabilities for the given GCS use for various UAVS (G.3.2.1.1)
COMPLEX INDICATOR OF LEVEL 1: **Perfection of auxiliary operations** (G.3.3)	
Perfection of preparatory operations (G. 3.3.1)	Suitability of the GCS to perform auxiliary transportation operations and preparation for launch (G.3.3.1.1)
Perfection of final operations (G.3.3.2)	Suitability of the UAV to perform auxiliary operations of disassembly, cleaning, packaging and transportation (G.3.3.2.1)
Perfection of auxiliary GCS operations (G.3.3.3)	Perfection of operations on viewing of videos (for example, search of the necessary record) (G.3.3.3.1)

Operational indicators of GCS quality are given in table 2.12.

Table 2.12. Expanded nomenclature of GCS ergo-design quality indicators. Operational indicators (G.4)

COMPLEX INDICATOR OF LEVEL 1 **Ease of GCS operation** (G.4.1)	
Complex indicator of the 2nd level	Single indicator
– (G.4.1.0)	Perfection of the GCS use during service operations accompanying implementation of the main and additional functions (G.4.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Ease of GCS maintenance** (G.4.2)	
– (G.4.2.0)	Perfection of preparatory and final operations, and also GCS regulation in the course of operation (G.4.2.0.1) GCS suitability to perform auxiliary operations of maintenance, storage, and disposal (G.4.2.0.2)
COMPLEX INDICATOR OF LEVEL 1: **GCS reliability** (G.4.3)	
GCS failure-free operation (G.4.3.1)	Preservation of the basic parameters of GCS operation in time and within the limits corresponding to the set operating conditions (G.4.3.1.1)
GCS durability (G.4.3.2)	Preservation of the basic parameters of GCS operation before the limit state is achieved at which their fulfillment becomes impossible. In the case of calculating the durability, it is determined the GCS service life or resource in conditions as close as possible to its specific operational process (G.4.3.2.1)
GCS maintainability (G.4.3.3)	Possibility of GCS urgent repair in field conditions (G.4.3.3.1) The average duration and complexity of the current GCS repair in stationary conditions (G.4.3.3.2)

Socio-cultural GCS quality indicators are given in table 2.13.

Table 2.13. Expanded nomenclature of GCS ergo-design quality indicators. Socio-cultural indicators (G.5)

COMPLEX INDICATOR OF LEVEL 1: **GCS social address and consumer class** (G.5.1)	
Complex indicator of the 2nd level	Single indicator
– (G.5.1.0)	Correspondence of the UAV to the structure of needs of a certain target audience (G.5.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: Compliance with the optimal GCS nomenclature (G.5.2)	
– (G.5.2.0)	Efficiency of GCS use in the operational or projected GCS system of a certain type (G.5.2.0.1)

COMPLEX INDICATOR OF LEVEL 1: **GCS moral aging** (G.5.3)	
– (G.5.3.0)	The GCS service life is limited by the introduction of new drones of higher quality (G.5.3.0.1)

Design and marketing indicators of the UAV quality are given in table 2.14.

Table 2.14. Expanded nomenclature of UAV ergo-design quality indicators. Design and marketing indicators (G.6)

COMPLEX INDICATOR OF LEVEL 1: **The degree of GCS compliance with the world level** (G.6.1)	
Complex indicator of the 2nd level	Single indicator
– (G.6.1.0)	The level of GCS design and ergonomic characteristics in comparison with the products of the leading manufacturers of similar products (G.6.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Compliance with the requirements of the potential target market** (G.6.2)	
– (G.6.2.0)	The degree of market demand for a particular GCS (G.6.2.0.1)

GCS design and environmental quality indicators are given in table 2.15.

Table 2.15. Expanded nomenclature of GCS ergo-design quality indicators. Design and environmental indicators (G.7)

COMPLEX INDICATOR OF LEVEL 1: **The nature and extent of the GCS impact on the environment** (G.7.1)	
Complex indicator of the 2nd level	Single indicator
– (G.7.1.0)	The impact of GCS on the environment during its life cycle (G.7.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Utilization degree of GCS materials** (G.7.3)	
– (G.7.3.0)	The output of recycled materials (G.7.3.0.1)

4.3 The expanded nomenclature of ergo-design quality indicators of starting devices

Let's define ergo-design quality indicators of starting devices (SD) (see Figure 2.3, 2.4). The SD as an object of ergo-design research is, of course, a purely technical

structure, where technical parameters are the most important. But ergonomic and operational issues are also important for this object. Let us consider them in tables 2.16–2.22

Figure 2.3. UAV Fulma starting device, Source http://www.laserlocation.ru/catalog/aircraft/UAV/3435/

Figure 2.4. UAV Lockheed Martin starting device, Source https://progress.online/oborona/871-lockheed-martin-narashchivaet-vynoslivost-razvedyvatelnyh-bespilotnikov

SD ergonomic quality indicators are given in table 2.16.

Table 2.16. Expanded nomenclature of SD ergo-design quality indicators. Ergonomic indicators (S.1)

COMPLEX INDICATOR OF LEVEL 1: **Ease of SD use for its intended purpose** (S.1.1)	
Complex indicator of the 2nd level	Single indicator

Correspondence of a SD design, its elements to the anthropometric characteristics of the human (S.1.1.2)	Taking into account the size of the human body and its parts in the size of the SD structural elements (S.1.1.2.1)
The operator`s physical load (severity of work performed) (S.1.1.3)	Dynamic physical activity (volume of work performed during SD transportation, preparation for use (for example, the use of a rubber shock absorber), configuration, adjustment, SD assembly (disassembly); weight of transported cargo) (S.1.1.3.1) Static physical activity (S.1.1.3.2) Deviation of working posture and movements from physiologically rational characteristics (S.1.1.3.3)
COMPLEX INDICATOR OF LEVEL 1: **Ease of management and control (controllability)** (S.1.2)	
Convenience of controls design (S.1.2.6)	Conformity of the form and construction of control bodies to ergonomic requirements (S.1.2.6.1) Conformity of sizes of control bodies to ergonomic requirements (S.1.2.6.2) Correspondence of the effort required to bring the controls in action to ergonomic requirements (S.1.2.6.3)
Ergonomic placement of controls (S.1.2.7)	Correspondence of the character of control movements of the operator to the SD functional state (S.1.2.7.1) Correspondence of distances to controls (taking into account the degree of importance and frequency of their use) to the anthropometric characteristics of the operator (S.1.2.7.2) Availability and sufficiency of protection controls means (S.1.2.7.3)
Rationality of the SD layout (S.1.2.8)	Compliance of SD sizes with the ergonomic requirements (S.1.2.8.1) Optimal placement of information display means and controls (S.1.2.8.2)

COMPLEX INDICATOR OF LEVEL 1: **SD assimilation** (S.1.3)	
Complex indicator of the 2nd level	Single indicator
Completeness and convenience of SD operation manual (S.1.3.2)	The level of completeness of the operating manual (S.1.3.2.1) Clarity of the operational instructions (S.1.3.2.2) Quality of material design (S.1.3.2.3)

COMPLEX INDICATOR OF LEVEL 1: **SD maintenance** (S.1.4)	
– (S.1.4.0)	Comfort and the rate of maintenance, repair, preparation for operation (S.1.4.0.1) The complexity of the maintenance and repair algorithm (S.1.4.0.2) Ease of access to adjustable and replaceable elements (S.1.4.0.3) Availability of technical means for diagnosing faults (S.1.4.0.4)
Ergonomics of operational documentation (S.1.4.2)	Completeness of operational documentation (S.1.4.2.1) Convenience of the material presentation structure, the levels of information decoding and re-coding (S.1.4.2.2) Quality of illustrations, schemes, graphic elements, and documentation format (S.1.4.2.3) Documentation storage capability (S.1.4.2.4)
Ergonomics of equipment and tools required for SD operation (S.1.4.3)	Ease of use of control, measuring, and testing equipment (S.1.4.3.1) Compliance of lighting equipment with the specified norms of general and local lighting (S.1.4.3.2) Convenience and safety of use of the tool during carrying out works in the given conditions (in hard-to-reach places, in the conditions of an overload) (S.1.4.3.3)
COMPLEX INDICATOR OF LEVEL 1: **SD hygiene** (S.1.5)	
SD physical factors (S.1.5.1)	Noise levels (S.1.5.1.1) Vibration levels (S.1.5.1.2)
SD chemical factors (S.1.5.2)	Presence of harmful components in materials and coatings, working fluids or gases used to operate the SD (S.1.5.2.1)
COMPLEX INDICATOR OF LEVEL 1: **SD safety** (S.1.6)	
– (S.1.6.0)	Safety level of the factors of mechanical origin (S.1.6.0.1) Safety level of the factors of chemical origin (S.1.6.0.2) Safety level of the influence of electric current (S.1.6.0.3) Safety level due to the product operation algorithm (S.1.6.0.4)

SD aesthetic quality indicators are given in table 2.17.

Table 2.17. Expanded nomenclature of UAV ergo-design quality indicators. Aesthetic indicators (S.2)

COMPLEX INDICATOR OF LEVEL 1: **Rationality of the SD form** (S.2.2)	
Complex indicator of the 2nd level	Single indicator
Functional and constructive conditionality of the SD form (S.2.2.1)	Compliance of the SD form with the purpose and operating conditions (UAV flight in the field conditions) (S.2.2.1.1) Correspondence of the SD form to its composition and layout (S.2.2.1.2) Suitability of the use of constructive methods of organizing the SD form elements (S.2.2.1.3)
Technological conditionality of the SD form (S.2.2.2)	Correspondence of the SD form to the requirements of its manufacturing technology (S.2.2.2.1)
COMPLEX INDICATOR OF LEVEL 1: **Integrity of a compositional-plastic SD form solution** (S.2.3)	
Harmony of the SD three-dimensional structure (S.2.3.1)	Interdependence of primary and secondary elements of the SD form in size, proportions and scale (S.2.3.1.1) The degree of SD scale and its elements (visual correspondence to the size of the human body) (S.2.3.1.2)
SD architectonic form (S.2.3.2)	Manifestation in the form of its structural nature loads (S.2.3.2.1) Visual balance of the SD three-dimensional, compositional and plastic structure (S.2.3.2.2)
Plasticity of the SD form (S.2.3.3)	Integrity of three-dimensional and plastic solution of the SD form (S.2.3.3.1) Correspondence of the volumetric and plastic solution to applied materials, and manufacturing technology (S.2.3.3.2)
Artistic and graphic expression (S.2.3.4)	Compositional validity of the arrangement of graphic elements on the SD parts (S.2.3.4.1) The degree of conformity of the nature of the fonts to the semantic value of the inscriptions. Expression of functional graphics (S.2.3.4.2)
Colour and graphic compatibility of elements (S.2.3.5)	Interdependence between colour and graphic elements (S.2.3.5.1) Subordination of colour and graphic elements to the general SD compositional and colour and graphic solution (S.2.3.5.2)
Colour and texture compatibility of elements (S.2.3.6)	Compatibility of different types of materials, composition, textures, coatings used in the SD with each other (S.2.3.6.1) Consistency of different types of materials, composition, textures, coatings with the SD shape, purpose, and operating conditions (S.2.3.6.2)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of production and the preservation of a marketable condition** (S.2.4)	
Fineness of contours (S.2.4.1)	Fineness of contours, fillets, and joints of the elements of the SD form (S.2.4.1.1)
Quality of the SD surface treatment (S.2.4.2)	Careful treatment of SD surfaces (S.2.4.2.1) Careful application of decorative and protective coatings (S.2.4.2.2)
Clarity of signs and accompanying documentation (S.2.4.3)	Quality of SD graphic elements, PDT, and promotional materials to it (S.2.4.3.1)
Resistance to damage (S.2.4.4)	Protection of the SD form elements and surfaces against damage, attrition, and decorative covering quality changes (S.2.4.4.1)

SD functional quality indicators are given in table 2.18.

Table 2.18. Expanded nomenclature of SD ergo-design quality indicators. Functional indicators (S.3)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of the main SD function performance** (S.3.1)	
Complex indicator of the 2nd level	Single indicator
Efficiency of SD use (S.3.1.1)	The degree of satisfaction with the SD during its intended use (S.3.1.1.1)
COMPLEX INDICATOR OF LEVEL 1: **Versatility of SD use** (S.3.2)	
The range of SD use for its intended purpose (S.3.2.1)	The range of SD conditions and capabilities for the UAV launch. (S.3.2.1.1)
COMPLEX INDICATOR OF LEVEL 1: **Perfection of auxiliary operations** (S.3.3)	
Perfection of preparatory operations (S.3.3.1)	Suitability of the SD to perform auxiliary transportation operations and preparation for launch (S.3.3.1.1)
Perfection of final operations (S.3.3.2)	Suitability of the SD to perform auxiliary operations of disassembly, cleaning, packaging and transportation (S.3.3.2.1)

SD operational quality indicators are given in table 2.19.

Table 2.19. Expanded nomenclature of SD ergo-design quality indicators Operational indicators (S.4)

COMPLEX INDICATOR OF LEVEL 1: **Ease of product operation** (S.4.1)	
Complex indicator of the 2nd level	Single indicator
– (S.4.1.0)	Perfection of the SD use during service operations accompanying implementation of the main and additional functions (S.4.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Ease of product maintenance** (S.4.2)	
– (S.4.2.0)	Perfection of preparatory and final operations, and also SD regulation in the course of operation (S.4.2.0.1) SD suitability to perform auxiliary operations of maintenance, storage, and disposal (S.4.2.0.2)
COMPLEX INDICATOR OF LEVEL 1: **SD reliability** (S.4.3)	
SD failure-free operation (S.4.3.1)	Preservation of the basic parameters of SD operation in time and within the limits corresponding to the set operating conditions (S.4.3.1.1)
SD durability (S.4.3.2)	Preservation of the basic parameters of SD operation before the limit state is achieved at which their fulfilment becomes impossible (S.4.3.2.1)
SD maintainability (S.4.3.3)	Possibility of urgent SD repair in field conditions (S.4.3.3.1) The average duration and complexity of the current SD repair in stationary conditions (S.4.3.3.2)

Socio-cultural SD quality indicators are given in table 2.20.

Table 2.20. Expanded nomenclature of SD ergo-design quality indicators. Socio-cultural indicators (S.5)

COMPLEX INDICATOR OF LEVEL 1: **SD moral aging** (S.5.3)	
Complex indicator of the 2nd level	Single indicator
– (S.5.3.0)	The SD service life is limited by the introduction of new drones of higher quality, as well as changes in social norms, cultural and value orientations (S.5.3.0.1)

Design and marketing indicators of the SD quality are given in table 2.21.

Table 2.21. Expanded nomenclature of SD ergo-design quality indicators. Design and marketing indicators (S.6)

COMPLEX INDICATOR OF LEVEL 1: **The degree of SD compliance with the world level** (S.6.1)	
Complex indicator of the 2nd level	Single indicator
– (S.6.1.0)	The level of SD design and ergonomic characteristics in comparison with the products of the leading manufacturers of similar (S.6.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Compliance with the requirements of the potential target market** (S.6.2)	
– (S.6.2.0)	The degree of market demand for a particular SD (S.6.2.0.1)

SD design and environmental quality indicators are given in table 2.22.

Table 2.22. Expanded nomenclature of SD ergo-design quality indicators. Design and environmental indicators (C.7)

COMPLEX INDICATOR OF LEVEL 1: **The nature and extent of the SD impact on the environment** (S.7.1)	
Complex indicator of the 2nd level	Single indicator
– (S.7.1.0)	The impact of SD on the environment during its life cycle (S.7.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Utilization degree of SD materials** (S.7.3)	
– (S.7.3.0)	The output of recycled materials (S.7.3.0.1)

4.4 Expanded nomenclature of ergo-design quality indicators of landing aids

Let's define ergo-design quality indicators of landing aids taking into account the fact that first, they concern purely technical objects and secondly, they have absolutely different principles of landing and, accordingly, absolutely different technical execution. Such principles of UAV landing as aircraft or parachute do not require the establishment of design and ergonomic indicators of the corresponding landing aids in the absence of such devices (setting requirements for parachutes is the objective of other studies). Nevertheless, the "human factor" is present to a large extent in case a grid or such a device as SideArm are used for UAV landing

Unfortunately, the SideArm and parameters are currently unknown. Therefore, we will develop a detailed nomenclature of design and ergonomic requirements for a landing aid in the form of a grid (Figure 2.5).

The landing aid, as well as SDs, from the point of view of design, is a technical structure where technical parameters are the most important. But ergonomic and operational issues are also important for this object. The expanded nomenclature of design and ergonomic quality indicators of landing aids is given in tables 2.23–2.29.

Figure 2.5. UAV Fulmar Landing in the grid, Source http://www.laserlocation.ru/catalog/aircraft/UAV/3435/

Ergonomic indicators of LA quality are given in table 2.23.

Table 2.23. Expanded nomenclature of LA quality ergo-design indicators. Ergonomic indicators (L.1)

COMPLEX INDICATOR OF LEVEL 1: **Ease of LA use for its intended purpose** (L.1.1)	
Complex indicator of the 2nd level	Single indicator
Correspondence of a UAV design, its elements to the anthropometric characteristics of the human (L.1.1.2)	Taking into account the size of the human body and its parts in the size of the LA structural elements (L.1.1.2.1)
The operator`s physical load (severity of work performed (L.1.1.3)	Dynamic physical activity (volume of work performed during transportation, preparation for use (installation of a grid), configuration, adjustment, assembly(disassembly); weight of transported cargo) (L.1.1.3.1)
COMPLEX INDICATOR OF LEVEL 1: **LA assimilation** (L.1.3)	
Completeness and convenience of LA operation manual (L.1.3.2)	Level of completeness of the LA operation manual (L.1.3.2.1) Clarity of the manual (L.1.3.2.2) Quality of material formatting (L.1.3.2.3)
COMPLEX INDICATOR OF LEVEL 1: **LA maintenance (**P.1.4)	
Complex indicator of the 2nd level	Single indicator
– (L.1.4.0)	Promptness of maintenance, repair, and preparation for use (for instance, installation of a grid) (L.1.4.0.1) Complexity of the maintenance and repair algorithm (L.1.4.0.2) Ease of access to adjustable and replaceable elements (L.1.4.0.3)
Ergonomics of operation documentation (L.1.4.2)	Completeness of LA operation documentation (L.1.4.2.1) Quality of illustrations, schemes, graphic elements, documentation format(L.1.4.2.2) Documentation storage capability (L.1.4.2.3)
Ergonomics of equipment and tools required for the LA operation (L.1.4.3)	Convenience and safety of use of the tool during carrying out works in the given conditions (L.1.4.3.1)
COMPLEX INDICATOR OF LEVEL 1: **LA safety** (L.1.6)	
– (L.1.6.0)	Safety level of the factors of mechanical origin (L.1.6.0.1) Safety level due to the product operation algorithm (L.1.6.0.2)

LA aesthetic quality indicators are given in table 2.24.

Table 2.24. Expanded nomenclature of LA ergo-design quality indicators. Aesthetic indicators (L.2)

COMPLEX INDICATOR OF LEVEL 1: **Rationality of the LA form** (L.2.2)	
Complex indicator of the 2nd level	Single indicator
Functional and constructive conditionality of the form (L.2.2.1)	Compliance of the LA form with the purpose and operating conditions (L.2.2.1.1) Correspondence of the LA form to its composition and layout (L.2.2.1.2) Correspondence of the use of constructive methods of organizing the LA form elements (L.2.2.1.3)
Technological conditionality of the LA form (L.2.2.2)	Correspondence of the LA form to the requirements of its manufacturing technology (L.2.2.2.1)
COMPLEX INDICATOR OF LEVEL 1: **Perfection of production and the preservation of a marketable condition** (L.2.4)	
Fineness of contours (L.2.4.1)	Fineness of contours, fillets, and joints of the elements of the LA form (L.2.4.1.1)
Quality of the LA surface treatment (L.2.4.2)	Careful treatment of LA surfaces (L.2.4.2.1) Careful application of decorative and protective coatings (L.2.4.2.2)
Clarity of signs and accompanying documentation (L.2.4.3)	Quality of UAV graphic elements, PDT, and promotional materials to it (L.2.4.3.1)
Resistance to damage (L.2.4.4)	Protection of the LA form elements and surfaces against damage, attrition, and decorative covering quality changes. (L.2.4.4.1)

LA functional quality indicators are given in table 2.25.

Table 2.25. Expanded nomenclature of LA ergo-design quality indicators. Functional indicators (L.3)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of the main LA function performance** (L.3.1)	
Complex indicator of the 2nd level	Single indicator
Efficiency of LA use (L.3.1.1)	The degree of satisfaction with the UAV landing function using LAs. (L.3.1.1.1)
COMPLEX INDICATOR OF LEVEL 1: **Versatility of LA use** (L.3.2)	
The range of LA use for its intended purpose (L.3.2.1)	The range conditions and applications of the given LA for the landing of various UAVs. (L.3.2.1.1)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of auxiliary operations** (L.3.3)	
Perfection of preparatory operations (L.3.3.1)	Suitability of the LA to perform auxiliary transportation operations and preparation for launch (L.3.3.1.1)
Perfection of final operations (L.3.3.2)	Suitability of the LA to perform auxiliary operations of disassembly, cleaning, packaging and transportation (L.3.3.2.1)

LA operational quality indicators are given in table 2.26.

Table 2.26. Expanded nomenclature of LA ergo-design quality indicators Operational indicators (L.4)

COMPLEX INDICATOR OF LEVEL 1: **Ease of the AL operation** (L.4.1)	
Complex indicator of the 2nd level	Single indicator
– (L.4.1.0)	Perfection of the LA use during service operations accompanying implementation of the main function (L.4.1.0.1) Perfection of preparatory and final operations, and also LA regulation in the course of operation (L. 4.1.0.2) LA suitability to perform auxiliary operations of maintenance, storage, and disposal (L.4.1.0.3)
COMPLEX INDICATOR OF LEVEL 1: **Ease of product maintenance** (L.4.2)	
– (L.4.2.0)	Perfection of preparatory and final operations, and also LA regulation in the course of operation (L.4.2.0.1) LA suitability to perform auxiliary operations of maintenance, storage, and disposal (L.4.2.0.2)
COMPLEX INDICATOR OF LEVEL 1: **LA reliability** (L.4.3)	
LA failure-free operation (L.4.3.1)	Preservation of the basic parameters of LA operation in time and within the limits corresponding to the set operating conditions (L.4.3.1.1)
LA durability (L.4.3.2)	Preservation of the basic parameters of LA operation before the limit state is achieved at which their fulfilment becomes impossible. In the case of calculating the durability, it is determined the LA service life or resource in conditions as close as possible to its specific operational process (L.4.3.2.1)
LA maintainability (L.4.3.3)	Possibility of urgent LA repair in field conditions (L.4.3.3.1) The average duration and complexity of the current LA repair in stationary conditions (L.4.3.3.2)

Socio-cultural LA quality indicators are given in table 2.27.

Table 2.27. Expanded nomenclature of LA ergo-design quality indicators. Socio-cultural indicators (L.5)

COMPLEX INDICATOR OF LEVEL 1: **LA moral aging** (L.5.3)	
Complex indicator of the 2nd level	Single indicator
– (L.5.3.0)	The LA service life is limited by the introduction of new drones of higher quality, as well as changes in social norms, cultural and value orientations (L.5.3.0.1)

Design and marketing indicators of the LA quality are given in table 2.28.

Table 2.28. Expanded nomenclature of LA ergo-design quality indicators. Design and marketing indicators (L.6)

COMPLEX INDICATOR OF LEVEL 1: **The degree of LA compliance with the world level** (L.6.1)	
Complex indicator of the 2nd level	Single indicator
– (L.6.1.0)	The level of LA design and ergonomic characteristics in comparison with the products of the leading manufacturers of similar products (L.6.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Compliance with the requirements of the potential target market** (L.6.2)	
– (L.6.2.0)	The degree of market demand for a particular LA (L.6.2.0.1)

LA design and environmental quality indicators are given in table 2.29.

Table 2.29. Expanded nomenclature of LA ergo-design quality indicators. Design and environmental indicators (L.7)

COMPLEX INDICATOR OF LEVEL 1: **Utilization degree of LA materials** (L.7.3)	
Complex indicator of the 2nd level	Single indicator
– (L.7.3.0)	The output of recycled materials (L.7.3.0.1)

4.5 Determination of ergo-design quality indicators of antenna and rotatory devices

Let's define the ergo-design quality indicators of antenna and rotatory devices (ARD) (see Figure 2.6). taking into account the fact that they belong to the so-called purely

technical objects as well as SDs. This means that their form is influenced mainly by technical considerations, although the "human factor", which can greatly affect the ease of maintenance of these devices (transportation, assembly, disassembly, etc.), should also be taken into account. That is, ergonomic and operational quality indicators in the ARD design have to be carefully studied. Let's define the expanded nomenclature of ergo-design requirements to ARDs in tables 2.30–2.36.

Figure 2.6. General view of the antenna and rotatory device of the UAV M-6-3 "Zhayvir" ground control station (SPCUV "Virazh", NAU)

ARD ergonomic quality indicators are given in table 2.30.

Table 2.30. Expanded nomenclature of ARD ergo-design quality indicators. Ergonomic indicators (A.1)

COMPLEX INDICATOR OF LEVEL 1: **Ease of ARD use for its intended purpose** (A.1.1)	
Complex indicator of the 2nd level	Single indicator
Correspondence of a ARD design, its elements to the anthropometric characteristics of the human (A.1.1.2)	Taking into account the size of the human body and its parts in the size of the ARD structural elements (A.1.1.2.1)

The operator`s physical load (severity of work performed) (A.1.1.3)	Dynamic physical activity (volume of work performed during transportation, preparation for use, configuration, adjustment, ARD assembly(disassembly); weight of transported cargo) (A.1.1.3.1)
COMPLEX INDICATOR OF LEVEL 1: **ARD assimilation** (A.1.3)	
Complex indicator of the 2nd level	Single indicator
Completeness and convenience of ARD operation manual (A.1.3.2)	Level of completeness of the ARD operation manual (A.1.3.2.1) Clarity of the manual (A.1.3.2.2) Quality of material formatting (A.1.3.2.3)
COMPLEX INDICATOR OF LEVEL 1: **ARD maintenance** (A.1.4)	
– (A.1.4.0)	Comfort and promptness of maintenance, repair, and preparation for operation (A.1.4.0.1) Complexity of the maintenance and repair algorithm (U.1.4.0.2) Ease of access to adjustable and replaceable elements (U.1.4.0.3) Convenience of auxiliary structural elements for operation preparation (A.1.4.0.4) Availability of technical means for diagnosing faults and convenience of troubleshooting (U.1.4.0.5)
Ergonomics of UAV operation documentation (A.1.4.2)	Completeness of UAV operation documentation (A.1.4.2.1) Convenience of material presentation structure (A.1.4.2.2) Quality of illustrations, schemes, graphic elements, documentation format (A.1.4.2.3) Documentation storage capability (A.1.4.2.4)
Ergonomics of equipment and tools required for the ARD operation (A.1.4.3)	Ease of use of control, measuring, and testing equipment (A.1.4.3.1) Convenience and safety of use of the tool during carrying out works in the field conditions (A.1.4.3.2)
COMPLEX INDICATOR OF LEVEL 1: **ARD hygiene** (A.1.5)	
Physical factors (A.1.5.1)	Ultrasound levels (A.1.5.1.1) Levels of ionizing radiation (A.1.5.1.2) Electrostatic field levels (A.1.5.1.3) Levels of electromagnetic fields of radio frequencies (A.1.5.1.4) Levels of microwave radiation (A.1.5.1.5)
COMPLEX INDICATOR OF LEVEL 1: **ARD safety** (A.1.6)	
– (A.1.6.0)	Safety level of the factors of mechanical origin (A.1.6.0.1) Safety level of the influence of electric current (A.1.6.0.2) Safety level of the factors of chemical origin (A.1.6.0.3) Safety level due to the ARD operation algorithm (A.1.6.0.4)

ARD aesthetic quality indicators are given in table 2.31.

Table 2.31. Expanded nomenclature of ARD ergo-design quality indicators. Aesthetic indicators (A.2)

COMPLEX INDICATOR OF LEVEL 1: **Rationality of the ARD form** (A.2.2)	
Complex indicator of the 2nd level	Single indicator
Functional and constructive conditionality of the ARD form (A.2.2.1)	Compliance of the ARD form with the purpose and operating conditions (transmission and receipt of information in the field) (A.2.2.1.1) Correspondence of the ARD form to its composition and layout (A.2.2.1.2) Correspondence of the use of constructive methods of organizing the ARD form elements (A.2.2.1.3)
Technological conditionality of the ARD form (A.2.2.2)	Correspondence of the ARD form to the requirements of its manufacturing technology (A.2.2.2.1)
COMPLEX INDICATOR OF LEVEL 1: **Perfection of production and the preservation of a marketable condition** (A.2.4)	
Fineness of contours (A.2.4.1)	Fineness of contours, fillets, and joints of the elements of the ARD form (A.2.4.1.1)
Quality of the ARD surface treatment (A.2.4.2)	Careful treatment of ARD surfaces (A.2.4.2.1) Careful application of decorative and protective coatings (A.2.4.2.2)
Clarity of signs and accompanying documentation (A.2.4.3)	Quality of ARD graphic elements, PDT, and promotional materials to it (A.2.4.3.1)
Resistance to damage (A.2.4.4)	Protection of the ARD form elements and surfaces against damage, attrition, and decorative covering quality changes (A.2.4.4.1)

ARD functional quality indicators are given in table 2.32.

Table 2.32. Expanded nomenclature of ARD ergo-design quality indicators. Functional indicators (A.3)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of the main ARD function performance** (A.3.1)	
Complex indicator of the 2nd level	Single indicator
Efficiency of ARD use (A.3.1.1)	The degree of satisfaction with the ARD information transmission and receipt function during its intended use (A.3.1.1.1)
COMPLEX INDICATOR OF LEVEL 1: **Versatility of AR use** (A.3.2)	
The range of AR use for its intended purpose (A.3.2.1)	The range of conditions and possibilities of use of this AR for application in another UAVS (A.3.2.1.1)

COMPLEX INDICATOR OF LEVEL 1: **Perfection of auxiliary operations** (A.3.3)	
Complex indicator of the 2nd level	Single indicator
Perfection of preparatory operations (A.3.3.1)	Suitability of the AR to perform auxiliary transportation operations and preparation for operation (A.3.3.1.1)
Perfection of final operations (A.3.3.2)	Suitability of the AR to perform auxiliary operations of disassembly, cleaning, packaging and transportation (A.3.3.2.1)

ARD operational quality indicators are given in table 2.33.

Table 2.33. Expended nomenclature of ARD ergo-design quality indicators. Operational indicators

COMPLEX INDICATOR OF LEVEL 1: **Ease of the ARD operation** (A.4.1)	
Complex indicator of the 2nd level	Single indicator
– (A.4.1.0)	Perfection of the UAV use during service operations accompanying implementation of the main functions (A.4.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Ease of the ARD maintenance** (A.4.2)	
– (A.4.2.0)	Perfection of preparatory and final operations, and also ARD regulation in the course of operation (A.4.2.0.1) ARD suitability to perform auxiliary operations of maintenance, storage, and disposal (A.4.2.0.2)
COMPLEX INDICATOR OF LEVEL 1: **ARD reliability** (A.4.3)	
ARD failure-free operation (A.4.3.1)	Preservation of the basic parameters of ARD operation in time and within the limits corresponding to the set operating conditions (A.4.3.1.1)
UAV durability (A.4.3.2)	Preservation of the basic parameters of ARD operation before the limit state is achieved at which their fulfilment becomes impossible. In the case of calculating the durability, it is determined the ARD service life or resource in conditions as close as possible to its specific operational process (A.4.3.2.1).
UAV maintainability (A.4.3.3)	Possibility of urgent ARD repair in field conditions (A.4.3.3.1) The average duration and complexity of the current ARD repair in stationary conditions (A.4.3.3.2)

Socio-cultural ARD quality indicators are given in table 2.34.

Table 2.34. Expanded nomenclature of ARD ergo-design quality indicators. Socio-cultural indicators (A.5)

COMPLEX INDICATOR OF LEVEL 1: **ARD moral aging** (A.5.3)	
Complex indicator of the 2nd level	Single indicator
– (A.5.3.0)	The UAV service life is limited by the introduction of new drones of higher quality, as well as changes in social norms, cultural and value orientations (A.5.3.0.1)

Design and marketing indicators of the ARD quality are given in table 2.35.

Table 2.35. Expanded nomenclature of ARD ergo-design quality indicators. Design and marketing indicators (A.6)

COMPLEX INDICATOR OF LEVEL 1: **The degree of ARD compliance with the world level** (A.6.1)	
Complex indicator of the 2nd level	Single indicator
– (A.6.1.0)	The level of ARD ergo-design characteristics in comparison with the products of the leading manufacturers of similar products (A.6.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Compliance with the requirements of the potential target market** (A.6.2)	
– (A.6.2.0)	The degree of market demand for a particular ARD (A.6.2.0.1)

ARD design and environmental quality indicators are given in table 2.36.

Table 2.36. Expanded nomenclature of ARD ergo-design quality indicators. Design and environmental indicators (A.7)

COMPLEX INDICATOR OF LEVEL 1: **The nature and extent of the ARD impact on the environment** (A.7.1)	
Complex indicator of the 2nd level	Single indicator
– (A.7.1.0)	The impact of ARD on the environment during its life cycle (A.7.1.0.1)
COMPLEX INDICATOR OF LEVEL 1: **Utilization degree of ARD materials** (A.7.3)	
– (A.7.3.0)	The output of recycled materials (A.7.3.0.1)

5. SUMMARY

Summing up the characteristics of ergo-design quality indicators, we emphasize that in modern socio-economic conditions, the UAVS production is constantly developing, growing, it is becoming a separate industry and, most importantly, it relies on evidence-based knowledge only. There is a need for original UAVS pre-design

ergonomic research based on the formation of a social standardization institution (in the broadest sense), and UAV samples involved in the production essentially perform the functions of the prototypes of new models, which should be created based on the functional principle – to design not products, but functional processes.

A new form of ergo-design knowledge application is increasingly being approved as a factor ensuring the greatest success in the sale of products by increasing their competitiveness in both domestic and foreign markets. In this situation, the involvement of ergo-design specialists in the product development process should take place as early as possible, i.e. at the earliest stages, in order to take into account, the human factor requirements to the fullest extent in the design of different UAVS types.

The subjective criterion of UAVS high-quality ergo-design is the formation of a sense of functional comfort in operators, when, for example, the workstation is treated as a system of functional and subject-spatial means that create comfortable and safe working conditions, and UAVs are equipped with sufficient technical means to perform certain functions. This approach to the design of unmanned aerial systems is promoted in this publication.

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