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Primary definitions of dependability of intense profession members

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Abstract. *Significance of the problem. The design of the activity of intense (extreme) profession members is due to the requirement to master new and previously unknown areas of industry and life. In the history of aviation, the matters of critical importance and calculation of required and sufficient properties of pilot and flight crew have been a subject of never-ending research for the purpose of regulation in the context of air transport operation. Up to the present moment, domain knowledge, theory and methods that would take into consideration the differences in the properties for standardization in flight operation management remain undefined. This problem of undefined domain knowledge and shortage of methods of calculation of the characteristics of civilian pilots and flight crew members are considered as extremely severe and still unsolved in the operation of civilian air transportation. Thus, the set of problems, the requirement for finding and developing new knowledge consists in the restriction of the available theories and methods of formalization, calculation of properties and management of human dependability. The relevance of this subject matter is reflected in fundamental and applied research conducted in Russia and abroad. This paper sets forth the primary definitions of dependability of intense profession members using the example of a commercial pilot. Definition of the problem of pilot dependability.Time scale is the universal foundation for the partition of the scope of the human operator (pilot) dependability concept. The primary property of human activity is the category of purpose. Purpose can be evaluated in structured subsumption of the concept of dependability. The technical substance of the category of purpose is structured with the definition of the nominal description of the objects: pilot (P), vehicle or aircraft (AC) and selected activity environment (E). The paper formalizes the definition of the human activity dependability problem. Axiomatics of pilot resource properties.The diverse nature of the human properties constitutes the fundamental problem of their description and standardization for the purpose of activity standards development. The properties have similarities, differences and independence. The paper sets forth axioms as the premises of the human resources theory under development. The premises are stated as axioms of equivalence, independence and completeness of properties, parameters and indicators of pilot resources. The practical significance of the axiomatics of the pilot resources properties consists in the fact that their formalized description allows obtaining algorithms for automated and expert technologies for flight operation management.Below are the formalizations of dependability definitions. Conclusion. The theoretical definitions of management efficiency and guaranteed management efficiency establish the concepts of discernibility of the space of successful activity outcomes. The axiomatics of pilot properties allow overcoming the fundamental difficulty of formalized description of the diverse nature of human properties and enables reliable consideration and calculation of the states for the purpose of flight operation management. The paper sets forth the definitions of pilot purpose, pilot dependability and dependability of three different kinds, i.e. individual, professional, operational, based on a fundamental temporal base of observation.*

Keywords: *pilot, purpose, management efficiency, guaranteed management efficiency, individual dependability, professional dependability, operational dependability.*

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1. Introduction

In the history of aviation, the matters of critical importance and calculation of required and sufficient properties of pilot and flight crew have been a subject of never ending research for the purpose of regulation in the context of air transport operation.

The subject of dependability of individuals (pilots) and groups (crews) in today's research is at the level of concepts and is limited to statistical and empirical estimations. There is currently no dependability theory of complex objects, individuals and groups of people equivalent to the technology dependability theory, therefore the development of such theory is of relevance. The dependability of human activity and a technical object have the same U-shaped lifecycle profile [1, 2]. Therefore, the technology dependability theory can be justifiably used in the development of the human and organizational object dependability theory. Human dependability indicators are different in their nature, dynamicsand intensity of temporal variation.

The difficulty of pilot activity description consists in the absence of a single concept to define the activity. There is along list of concepts used to describe the properties of human activity: professionalism, occupational aptitude, availability, training, preparedness, dependability, responsibility, fitness for work, working efficiency, profession, qualification, experience [3, 4]. In general, the abundance of conceptual descriptions may be considered as a problem of identification of the object of activity.

The competitive environment of the open global air transportation market is leveled against the standardization of airline activities. Air disasters of the last few decades highlight the primary causes, i.e. professional properties deficiency and excessive workload of flight crews in civil aviation operations [5]. This situation is caused by not only the pressure of the business environment, but also by the critical insufficiency of scientifically grounded methods of managing flight operations in terms of human resources.

Given the above, the set of problems, the requirement for finding and developing new knowledge consists in the restriction of the available theories and methods of formalization, calculation of properties and management of human dependability. The relevance of this subject matter is reflected in numerous fundamental and applied research conducted in Russia and abroad [6, 7, 8]. This paper sets forth the primary definitions of dependability of intense profession members using the example of a commercial pilot.

2. Logical foundations of the professional activity theory

The activity theory distinguishes the types of activities that can be performed by all or the majority of individuals in a society, and the professions with special requirements [3]. In this paper, professions with special requirements like the profession of commercial pilot are referred to as intense or extreme. The design of the activity of such profession members is due to the requirement to master new and previously unknown areas of industry and life or those having an enduring critical relevance to the outcome of an activity.

Identifying the properties of any object, whether material or immaterial, artificial or natural, is not a trivial task. We structure this task as follows: a) search for the concept that best generalizes and corresponds with the object's properties; b) search and establishment of the required base of structurization and observation (measurement, evaluation) of the property; c) identification of the term that best corresponds with the states (changes) of the property.

Let us clarify the task in terms of theory of concepts (subdiscipline of logic). Each concept has its scope and content. The evaluation of abstract concepts (categories) is done through the following axiomatic heuristic statement: a) evaluation of the type of concept in terms of scope; b) identification of the basis of its partition; c) contents and presence of attributes; d) establishment of relations of concepts [9, 10].

Logical classification of concepts. "The sum of single concepts designating such objects is the scope of concept". An example: the scope of the concept of "flight" includes the sum of individual concepts of "airplane", "bird". "The sum of attributes conceivable within a concept identical in all specimens of the class is the contents of the general concept [11, p. 92]. An example: the concept of class "flight" involves the attributes of movement in a three-dimensional space for all objects (specimens): aircraft, birds. The scope and contents of a concept are in inverse relations: while enriching the contents we decrease the scope and vice versa. The law works for reconcilable concepts, when an attribute characterizes a part of the scope of the initial concept, and for concepts having subsumption relations.

Types of concepts in terms of scope. A single concept contains one object or element: "Aeroflot", "Delta Airlines". Single concepts have no scope, as they signify one object rather than a class of objects. Single concepts have contents, as they have not less than one attribute. A general concept contains several or a set of objects, e.g. "airport", "airline". General concepts may be registering and infinite. In registering concepts a set of elements may be taken into consideration and recorded, e.g. "flight". In infinite concepts the set of elements is not limited, not estimable and has an infinite scope. For example, "aviation". This is explained in the diagram (Figure 1).

Types of concepts in terms of contents. In terms of contents, four pairs of concepts are distinguished. An abstract concept designates abstract ideal existence. An object's attributes form an independent object of thinking, a thought without an object, e.g. "risk", "dependability". A concrete concept designates a real object, e.g. "airplane", "aviation" (a set of real numerable objects). The concepts can be generalized or determined. General concepts may be both concrete and abstract. For example, the concept of "pilot"

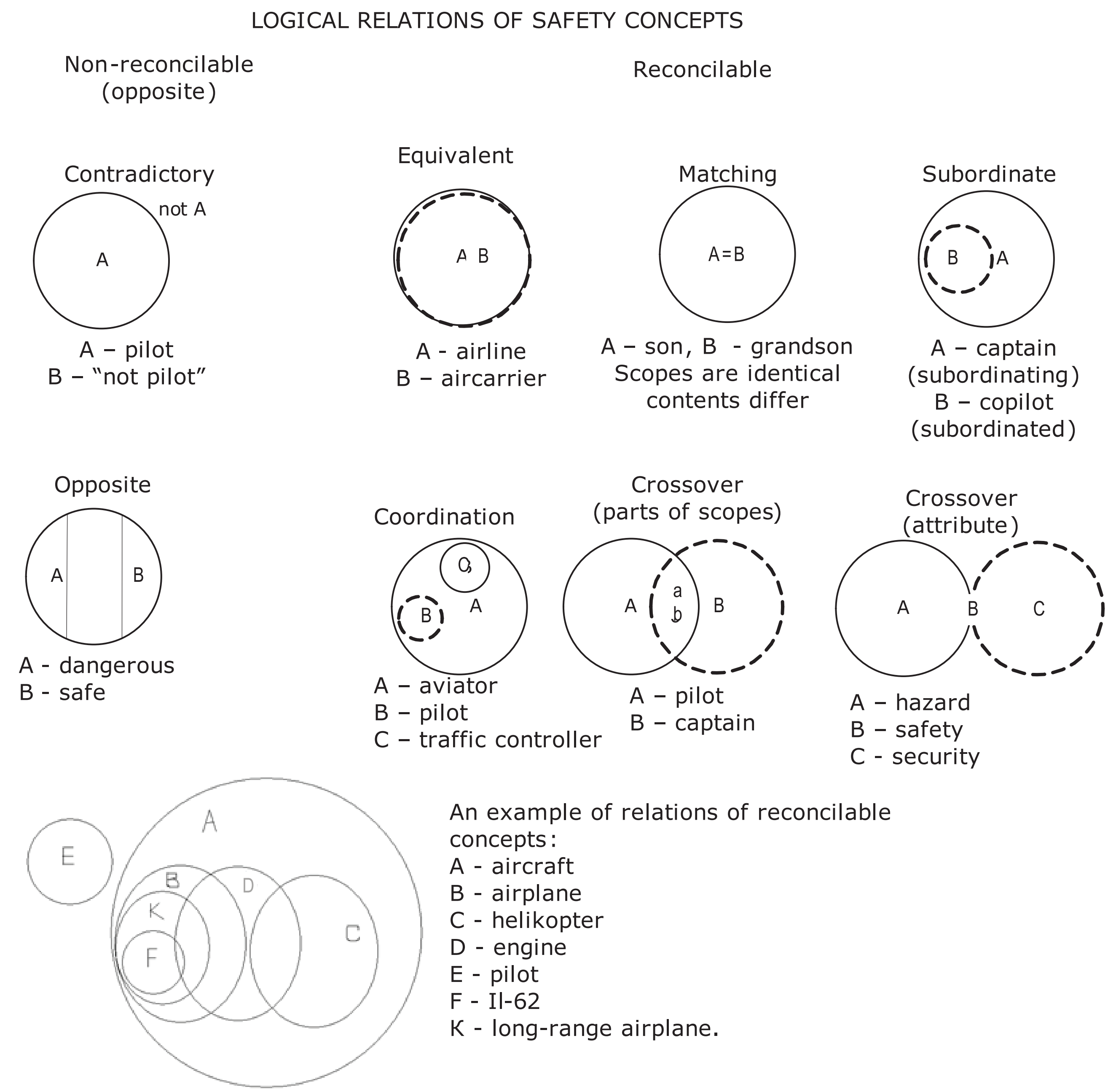

Figure 1. Logical relations of the safety concepts

is general and concrete, while the concept of "piloting" is general and abstract. A positive concept is a concept that includes attributes of object, a negative concept does not. An example: "hazard" and "safety". Coexisting concepts denote objects that designate the existence of the other, e.g. "pilot" and "aircraft". In independent concepts the objects are conceived separately: "city", "forest". A collective concept consists of a finite set of homogenous objects as a whole, e.g. "fleet", "crew", "air squadron". Non-collective concepts designate uncountable single objects, e.g. "sky", "safety", or a countable set of heterogeneous objects, e.g. "aviation".

As it is shown in [12], the main property of the pilot's activity is designated by the category of purpose (as the ability to control an aircraft in a three-dimensional space). The observer's position that defines the best possible discernibility of the object's properties is called the observation base. There are multiple types of observation bases: time, space, group and their combinations: time-space, time-group, space-group. The most universal observation bases are abstract concepts or categories, i.e. space and time (G. Klir) [13]. Therefore, this paper adopts the time scale as the basis for partition of the scope of the human operator (pilot) dependability concept. In our opinion the property of purpose can be evaluated in structured subsumption of the concept of dependability: individual, professional, operational. This partition enables the substantiation of the definition below.

3. General problem definition of dependability calculation of pilot properties and states

The technical content of the category of purpose is structured by the specified nominal description of objects: pilot (P), vehicle or aircraft (AC) and chosen activity environment (E) of the three-dimensional space. Attributes of observation become possible after the establishment of the following four types of subject-objectivity: self-observation by pilot of own activity P→P; observation of aircraft by pilot P→AC; observation of environment by pilot P→E; observation by pilot of the aircraft-environment interaction P→(AC↔E). The sum of these objects and relations is the common task of purpose of pilot's activity in flight A_{nom}:

$$A_{nom} = \left\{ \begin{array}{c} P \to P \\ P \to AC \\ P \to E \\ P \to (\mathrm{AC} \leftrightarrow \mathrm{E}) \end{array} \right\}.$$

The flight defined by the purpose is a process P_{fl} with the finite sum of n operations consisting of: (1) standardized P_{st}; (2) unexpected deviations from flight plan due to work environment P_{we}; (3) random changes of flight parameters P_m. The parameters of operations (1) and (2) are the parameters of purpose. The parameters of operations (3) are generated by the pilot based on the analysis of the parameters deviations Δω from the nominal values ω_{nom}:

$$P_{fl} = n \sum_{i=1}^{\omega} (\omega_{nom} - \Delta\omega) V_{\omega_i},$$

where V_{ω_i} is the parameter change rate, $d\omega/dt$.

In accordance with the organization theory [14], the pilot's activity is described by the set A of allowed actions y=($y \in A$). The result of activity is $z\, A_0$, where A_0 is the set of allowed results. The connection between ($y \in A$) and ($z \in A_0$) is fuzzy and non-limiting. The pilot can compare the results having preferences $R_{A_0} \in$, where R_{A_0} is the preferences, $\Re_{A0}$ is the set of possible preferences. The possible R_{A_0} is in reciprocation with the value of parameter $r \in \Omega$ out of subset Ω of real axis $\Re^1$. While choosing action $y \in A$ the pilot is ruled by a) own preferences and b) the effect (estimation) of the chosen action on the activity result $z \in A_0$. The sum of (a) and (b) forms a law $W_I(\cdot)$ that characterizes the situation of which the information is reflected by variable I. The choice of action is defined by rule of individual rational choice that is dictated by the standards of flight operation, professional experience and identifies a set of preferable actions:

$$P^{W_I}\left(\Re_{A_0}, A, I\right) \subseteq A.$$

The objective function of control actions $u \in U$ equals:

$$K(B) = \max_{y \in P(u)} f_0(u, y).$$

D 1. The value $K(u)$, $u \in U$ is called efficiency of control.

D 2. If the pilot's actions entail the least preferable choice in the space of successful outcomes of activity, the value $K(u)$, $u \in U$ is called the guaranteed efficiency of control:

$$K(u) = \min_{u \in U} f_0(u, y).$$

Thus, the task of control is formulated: to find the allowable actions in the space of successful outcomes that lead to the best results, i.e. to optimal control: $K(u) \to \max$. The control model shown in this paper is the initial representation (statement) for the design of the resource system of pilot dependability. Subsequent formalization for the purpose of calculation of the properties and states of human resources in this class of tasks of the activity theory appears to be impossible using the tools of the classic set theory. The task is formalized in the pseudophysical activity model, i.e. relation between actions and outcomes of which the content is set forth in [4, 14].

4. Axiomatics of the properties of pilot resources

The diverse nature of the human properties constitutes the fundamental problem of their description and standardization for the purpose of activity standards development. The properties have similarities, differences and independence. For example, different and independent properties, e.g. professional experience, social maturity, individual's age are similar and commensurate in lifetime. The similarity of properties allows overcoming the mentioned problem by choosing a limited number of properties. The mutual similarity of properties allows using known indicator and parameter values to identify the values of unknown indicators and parameters in which the considered characteristics are examined "in isolation from all the other ones" [13, p. 348-354]. The substantiation may be in the form of theoretical postulates and axioms. For the first time this paper sets forth axioms as the premises of the new resources theory of human activity.

The logical conclusions of the suggested axioms are interrelated. The truth of the sum of conclusions is based on their consistency. The axioms are drawn from experience (empirical observation), formulated in heuristic statements, plausible judgments and conclusions. The following premises are stated as axioms of equivalence, independence and completeness of properties, parameters and indicators of pilot resources. The practical significance of the axiomatics of the pilot resources properties consists in the fact that their formalized description allows obtaining algorithms for automated and expert technologies for flight operation management.

The proposed axiomatics of the properties of a non-numerical object (human being) and complex object as formally reflected by measures of *regularity, continuity and distance.* The properties possess partial regularity Q of subset and defined as a binary relation over a set of states or a parametric set: $Q \subset V_i + V_i$ and satisfies the following requirement: reflectivity of $(x, y) \in Q$; antisymmetry when

$(x, y)\in Q$ and$(y, x)\in Q$, then $x=y$; transitivity, i.e. if $(x, y)\in Q$ and $(y, z)\in Q$, then $(x, y)\in Q$; if $(x, y)\in Q$, then x is the predecessor of y, while y is the successor of x; if $(x, y)\in Q$ and there is no $z\in Q$ such that $(y, z)\in Q$ and $(z, x)\in Q$, then x is the immediate predecessor of y, while y is the proximate successor of x; connection, i.e. for all $x, y\in V_1$ if $x\neq y$, then $(x, y)\in Q$ or $(y, x)\in Q$.

The axiomatics of properties enables the simplification of the design process and relatively simple calculations in adopted scales and units of time as shown in [11]. The system of pilot resources developed based on the described axiomatics of properties for the first time enables the acquisition of algorithms for automated and expert control systems [14].

5. Definition of resources (states) of pilot reliability

The resource of purpose is defined by the concept of dependability.

D 3. The ability to control an aircraft in a three-dimensional airspace is called the pilot's resource of purpose.

D 4. Dependability is the set of properties and states of the object within the metric of the standard activity space.

In [4, 13] dependability is structured in three forms: resources of individual dependability, resources of operational dependability, resources of professional dependability. The solution is substantiated by the single *basis*, i.e. discernibility of each group of resources in **time**.

D 5. *Individual dependability* is the sum of human evolutionary specific biological properties in the environmental conditions. Individual dependability has the meaning of specific evolution that is infinitely longer that an individual human life.

D 6. *Professional dependability* is the sum of human properties gained within a profession in the chosen professional environment. Professional dependability has the meaning of the duration of professional activity of an individual within the period roughly between 20 and 60 years.

D 7. *Operational dependability* is the sum of conditions and states of flight defined for the realization of managerial activity in the chosen purpose environment. Operational dependability is observed within the operational period of one year.

6. Conclusions

The category of purpose of activity names the object of WHAT exactly is performed as part of practical activity, while the category of dependability names HOW to observe (measure, evaluate) the object.

The next task is the detailed development of the categories of purpose and dependability in their linguistic, ontological and technical essence. The goal of linguistic analysis is to identify the objective semantics of words. The ontological task is to identify the subject area and the subject-objectivity.

The technical substance defines the terms, structure of activity and method of observation of the object. This approach constitutes the foundation of the presented method of technical modeling of pilot activity and implementation of the calculation and management design [15].

The theoretical definitions of management efficiency and guaranteed management efficiency establish the concepts of discernibility of the space of successful activity outcomes.

The theoretical foundations and deduced definitions allow developing expert systems and automated systems of prediction and prevention of flight accidents during organization and performance of air transportation operations [15] (Figure 2).

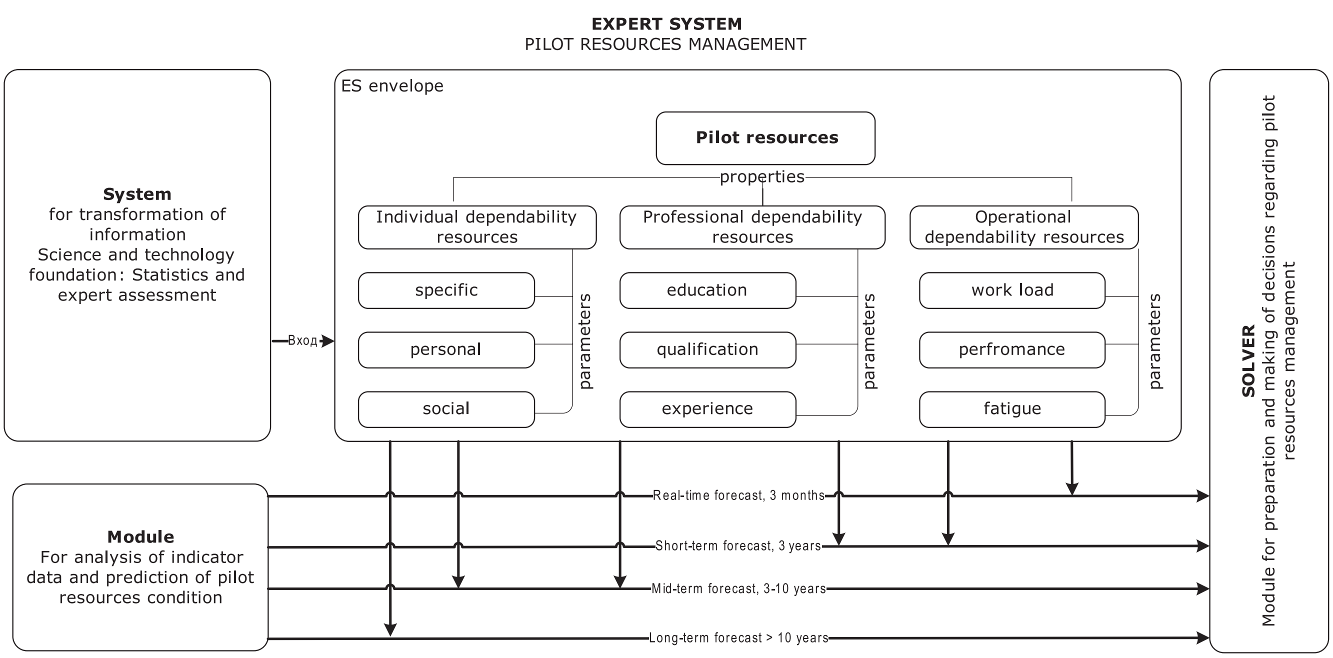

Figure 2. Pilot resources management ES

The axiomatics of pilot properties allow overcoming the fundamental difficulty of formalized description of the diverse nature of human properties and enables reliable consideration and calculation of the states for the purpose of flight operation management.

The paper sets forth the definitions of pilot purpose, pilot dependability and dependability of three different kinds, i.e. individual, professional, operational, based on a fundamental temporal base of observation.

Thus, new foundations may be developed for the activity theory and task definition of the property of activity of people of any profession may be formalized. For intense profession members the dependability category may be universal. For workers of education and science competence and qualification may be the right concepts. In professions involving physical labour that may be productivity and efficiency.

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