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Development of an alternative dependability terminology

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Abstract. Aim. *This paper contains a brief historical overview of the evolution of the technology dependability theory. The evolution of the concept of dependability reflects the unsolved problem of presentation of the scope and content of concepts in the dependability theory of technical objects. It is proposed to logically elaborate and deduce the terms based on the pseudophysical propositional logic. The paper presents an approach to solving the problem of introduction of the concept of an object's intended use and deduction of alternative basic definitions of dependability. The aim of the paper is to examine the feasibility of applying the modern technology dependability theory to subsequent theoretical developments and practical application of the concept of reliability of organizations, social groups and individuals.* **Methods.** *The problem of the terminology and years-long search for the definitions of dependability consists in the deficiency of the academic development of the subject matter in philological, philosophical and logical terms. Certainly, such research is to be conducted by experts in the appropriate fields of knowledge. Let us make our own contribution as regards the subject matter of this paper. The author suggests a structural approach to terminological research. Essentially, it consists in the following. If identifying the signs of the concept content is complicated, structuring the concept scope may be an option. The structuring is done using universal observation bases: time, space, groups and their combinations: time-space, time-group, space-group. For that purpose, a special terminology is required. The category of "intended use" as an object's property is introduced. The concept of intended use is large in scope, is more abstract than the concept of dependability. Let us note that quality standards were developed under the assumption that the intended use is the compliance of an object's characteristic with the requirements. Russian standards prioritized the dependability concept, where the regulatory descriptions, definitions, such as "the ability to perform the required (specified) functions, (an object's) ability to function", "to function as and when required", "functional dependability", "parametric dependability", "requirements specified in the documentation" are simply generalized by the category of intended use Such descriptions are none other than an indication of the property of an object's intended use. For instance, an object's ability to move in space is a property of the intended use, not dependability. Thus, all the terminological searches in terms of dependability standardization demonstrate an unjustified reduction of the concept of intended use to the concept of dependability. The introduction of the category of intended use solves the problems of terminology in the dependability theory. The author suggests the following definition of intended use. Intended use is the property of an object defined by the natural origin or designed application. Dependability is a set of states as the measure of concordance with the intended use of an object.* **Conclusion***. The evolution of the concept of technology dependability reflects the unsolved terminological problem in the dependability theory of technical objects. The problem of terminology largely consists in the ambiguous use and confusion of ontological terms. Deduction of such terms based on pseudophysical logic and introduction of the category of object's intended use is the main result of this paper in terms of the introduction of an alternative noncontroversial structure and content of dependability-related terms. The suggested approach is recommended to be used for revision of the existing standards.*

Keywords: *dependability, terminology, ontological terms, property, state, event.*

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1. Introduction

Standard descriptions of dependability were developed for engineering, industrial products, machines and devices. The research of dependability is associated with the theory of life safety and risks. This paper examines the problem of terminology as part of dependability standardization. The aim of the paper is to examine the feasibility of applying the modern technology dependability theory to subsequent theoretical developments and practical application of the concept of reliability of organizations, social groups and individuals.

2. Problem of terminology in the dependability theory of technology

Since the introduction of the term of industrial product dependability and emergence of the first respective documents in the 1950s, there has been an ongoing discussion of the problem of dependability terminology, specificity as regards the specification of the fundamental term of "dependability". The regulatory framework includes Russian and interstate standards: GOST 13377-67; GOST 13.337-75; GOST 27 002-83; GOST 27.002-89; GOST 27.002-2015; GOST R 51901.3-2007 (IEC 60300-2: 2004); GOST ISO 9000-2011; GOST R 27.002-2009. The concept of dependability is examined much wider in standards related to the terminology of quality, risk, safety: GOST 15467-79; GOST R 51901-2002; GOST R 51897-2002; GOST R 51898-2002; GOST 51901.14-2005 (IEC 61025: 1990); GOST R 51901.12-2007; GOST R 53480-2009; GOST R ISO/IEC 31010-2011.

The semantic descriptions of the concept of dependability in the documents can be reduced to the following: "… property of the system to perform the task, … specified functions, … specified indicators within the given ranges, … parameters characterizing the ability to perform the required (specified) functions…" The same is true with the semantic descriptions in the IEC dependability standards: "the ability (of an object) to function as and when required".

The concept of *good state* of a technical device is the initial description that defines the content and scope of the concept of dependability. As machines can operate in a partially faulty state, the definition of [good/faulty state] becomes blurry. The introduction of the term "failure" defines the impossibility to use an engineering product. That caused the definition of dependability through *reliability* and additionally: durability, maintainability, storability. Next, the concept of the *up state* was introduced. GOST R 27.002-2009 defines dependability through *availability*, while GOST 27.002-2015 [3] defines it through *ability*. Thus, the evolution of terminology from 1950 to this day shows roughly the following sequence of replacement of the concept of dependability with other generalized "explicative" concepts:

DEPENDABILITY≅
< (good state) → (reliability) → (operability) → (availability) → (ability) >.

A detailed account of the content and historical analysis of the regulatory documents on dependability terminology was presented in [1, 2]. In the author's opinion, the introduction of standard [3] does not resolve the problem of standardization of the dependability terminology. Let us examine the basic definitions in this standard.

Section 3 "Terms and definitions", Item 3.1 "Basic definitions": "3.1.5. **dependability**": The property of an object to maintain in time the ability to perform the required functions in specified modes and conditions of operation, maintenance, storage and transportation. Note 2. Dependability is a composite property that, depending on the intended use and operating condition of the object, may include reliability, maintainability, restorability, durability, storability, availability or certain combinations of such properties". Further in the standard, the above properties are defined. In Item 3.2 "States", the following definitions are introduced: "3.2.1 good state: …, 3.2.2 faulty state: …". In other words, the above properties are also considered as states.

In Item 3.4 "Failures, defects, damage", the terms "failure" and "damage" are defined as *events*, while "defect" is defined as the object's *non-compliance* with the requirements specified in the *documentation*. The "causes of failure are provoked", while the "consequences of a failure are conditioned" in a simultaneous and joint total: *phenomena, processes, events and states*. In Item 3.5.5, restoration is considered both as a process and an event. The standard is full of such cases.

The concept of *dependability*, without any doubt, is abstract, i.e. is a category. That is the main reason of the terminology problem and unchanging need to define dependability through other concepts. To make matters worse, compound words are used, such as reliability, maintainability, durability, restorability, etc., which further complicates the solution of the problem. In logic, the definition of a concept that leads to a term is based on the content (signs), rather than the scope of such concept. If signs are successfully identified, the definition is considered to be strong, quantitative, suitable for object properties calculation. Otherwise the definition comes down to a simple replacement with another concept or several concepts ("dependability is reliability", etc.). In other words, the definition of the term is descriptive, weak and ill-suited for quantitative estimation. In our opinion, identifying the signs of the *content* of the concept of dependability "directly" does not appear to be possible.

The problem of the terminology and years-long search for the definitions of dependability consists in the deficiency of the academic development of the subject matter in the philological, philosophical and logical terms. Certainly, such research is to be conducted by experts in the appropriate fields of knowledge. Let us make our own contribution as regards the subject matter of this paper.

3. Research of the dependability terminology

The philological aspect. The philological examination of the concept of dependability is possible in the lexical and grammatical aspects. The word "dependability" is often searched for in technical literature with no tangible results. Normally, the definition is descriptive and repeats the content set forth in technical documents. Encyclopedias, specialized and explanatory dictionaries enable defining the scope of a concept, but identifying the signs of the content, which is required for term derivation, proves to be unsuccessful.

In the lexical-grammatical aspect, the morphological structure of the word "dependability" consists of the prefix de-, root -pend- and suffix -ability. The lexical-grammatical class of the word *dependability* presents a suffix abstract noun that designates a quality (property) or state of an object, motivated by the adjective *dependable* with the meaning of an abstract sign. "Nouns with a suffix represented with the morpheme -ability with the meaning of "carrier of a sign" designate an abstract state [4, p. 164]; … with the meaning of abstract sign, designate a state with an abstract meaning of a sign, property" [4, p. 177]. It has been theoretically established that nouns are motivated (governed) by adjectives in pairs: "dependability – undependability". Out of this context and the general linguistic definitions, it is impossible to identify, what exactly the noun "dependability" and the adjective "dependable" designate: a property, a state, a sign of an object. Thus, attempted philological research does not bring us closer to the solution.

Analysis of ontological terms in logic. Let us examine how terms, definitions and reducibility of terms are established in logic. Abstract concepts (categories) are also called ontological terms (time, space, beginning, end, cause) that are later specified (defined) with logical terms. The theory of concepts, a sub-discipline of classical logic, has it that the scope and content of categories are the most difficult to define. Furthermore, the most abstract categories such as entity, thing, quality and others are not generalizable at all in terms of scope and their sign cannot be identified in terms of content.

First, the term (object) is specified. Then, the predicate (*sign*) is specified. The term and the predicate are correlated. "The predicate "red" (and the sign corresponding to the "redness") is one-place. The predicate "bigger" (and the size sign "bigger") is two-place. A predicate with the correlation ≥ 2 is n-place. One-place signs are called properties. N-place signs are called relationships [5, p. 61], i.e. assertions with multiplace predicates. Reducing terms to simple ones is the most important problem of logical analysis of scientific knowledge. "Defining a term means establishing its meaning using other terms, whose meaning is already known" [5, p. 228]. Terms are subdivided into initial and derived ones.

D-1. The term t^1 is initial in relation to the term t^2, while t^2 is derivative in relation to t^1 if and only if t^1 is used in the creation (specification of the meaning) of t^2" [5, p. 62].

The creation (introduction) and definition of ontological terms is the most important part of the problem of this paper as regards the terms "property", "state", "event", "situation", "process".

The categories of "property" and "state". There are no definitions of the concepts of "property" and "state" in the technology dependability standards. Meanwhile, the difference between those concepts is not trivial. According to Aristotle, "a *property* (hexis) is the manifestation of a certain activity by that which possesses and what it possesses; such an arrangement towards another, for example, health, is a certain property"…, "a transient property or *state* (pathos) is a property subject to possible changes; various manifestations of such properties and applications" [4, p. 244]. A property is a quality, a state is a quantity.

<u>Examples.</u> (1) A body has the property of weight and can be in the states of movement and rest. (2) The property of water manifests itself in the states of liquid, solid, gaseous (vaporous), crystalline. It can be said that water has a "composite property" and manifests itself in the "sub-properties" of liquid, ice, vapour, snow. However, it is preferable to explain the states.

Thus, in the existing standards, the definition of dependability as a *property* of an object is up to discussion and selection. In our opinion, the concept of dependability is a *state* of an object. That is substantiated below.

The categories of "event" and "process". In [8], the following definitions are introduced:

113-01-04 event: Something that takes place, happens, occurs in a random point in space-time;

113-01-06 process: A time sequence of correlated events.

Those definitions do not satisfy the objectives of this paper, as they are descriptive, weak. In scientific literature, the definitions of the terms under consideration are often missing, are not reduceable to each other or equated to each other. It would be sufficient to note that in D.A. Pospelov's book [Situational management] [9] the concept of "situation" is not defined. According to A.A. Zinoviev, "If X is a statement, then $\downarrow X$ is a term of event (or state). Events exist or do not exist in a certain given or any situation" [5, p. 166]. Clearly, the terms "event" and "state" are equalized to each other. It is explained that a situation is defined by specifying the following: a) spatial area, b) time, c) event or set of events, d) combination of (a, b, c) is express; or follows from the context. However, out of the above logical construct do not directly follow the definitions of the terms "event", "situation" and others. In our opinion, the definitions can be deduced only using the pseudophysical (pseudological) method.

Deduction of the term of pseudophysical logic. The pseudophysical logic (PL) (term coined by D.A. Pospelov [9]) of the correlation between time, space, causality and their combinations allows deducing the definitions required for subsequent explanation. Let $|O_i|$ be the term, the observed object. Let us represent the following definitions and examples of reality.

D-2. An object's transitions in mapping spaces are called *ascending* if directed towards higher dimensionality: $O_i : s_i\, s_{i+1}, \ldots, s_{i+k},\ i \in \overline{1,n}$, where n is the number of an object's states.

An example: the moment an aircraft lifts off the runway and starts moving in a three-dimensions space.

D-3. An object's transitions in mapping spaces are called *descending* if directed towards lower dimensionality:, $O_i : s_i\, s_{i-1}, \ldots, s_{i-k},\ k \in \overline{1,n-1}$ number of transitions.

An example: the moment of an aircraft's landing and transition to movement in a two-dimensional space.

D-4. An object's transitions in mapping spaces are called *symmetrical* if directed either way of the same (higher or lower) dimensionality: $O_i : s_i\, s_{i\pm1}, \ldots, s_{i\pm k}$.

An example: a) moment of the acceleration run at the decision speed; b) the moment at the landing decision point height when the decision is made to land or execute a go-around.

D-5. Object mapping in ascending transitions is called the *involution* of object description data.

D-6. Object mapping in descending transitions is called the *convolution* of object description data.

Defining the terms "event", "situations" is only possible at the convergence of the temporal and spatial logic. A complete derivation of ontological terms is only possible at the convergence of the temporal, spatial and causal logic, which requires additional research.

D-7. A representation of an object in transitions from space to space s_i in the moment in time t_i we call an *event*: $e_i : \left(t_i s_i\, s_{i\pm1}, \ldots, s_{i\pm k}\right)$, where e_i is the object mapping operator for transition from space to space.

An event, set E, $e_i \in E$ is the association of the PL of relationships between the time and the space $e_i\left(t_i, s_i\right)$.

D-8. The set of associations of the PL of relationships between the time and the space we call a situation.

In the above definitions and examples: a situation is a set (beginning of movement and stopping of an object, takeoffs and landings, decisions made) of events in ascending, descending, symmetrical transitions.

In [8], there is no definition of the concept of "state". Let us introduce the following definition.

D-9. A **state** is a parameter, set of parameters of an object's properties within the observed time intervals ("113-01-10 time interval): Part of the axis of time limited by two moments" [8]).

In this definition, the concept of state is defined as the **parameter** of *commensuration* of indicators (combined and simultaneous). For instance, the speed of a vehicle is *commensurated* with two indicators: distance and time.

4. Solving the problem of development of the dependability terminology

The structural approach. The author suggests a structural approach to terminological research. The essence of such approach consists in the following. If identifying the signs of the concept *content* is complicated, structuring the concept *scope* may be considered. The structuring is done using universal observation bases: time, space, groups and their combinations: time-space, time-group, space-group [6]. It has been empirically established that the dependability of an object of any nature changes in time in steps, the so-called U-shaped profile: entry (below the norm), normalization, ageing (below the norm). Subsequently, the dependability of any object can be reliably observed (measured, evaluated) according to the U profile. For that purpose, a special terminology is required.

We suggest a strict hierarchic structure of terms. An object has a name. The intended use of an object specifies its property. A property is observed (measured, evaluated) in states or parameters. States are formed by a set of indicators. Indicators are specified based on values. For the purpose of calculating an object's properties, an information unit (IU) is defined with an n-placed five:

$\{1$, assignment $\subseteq 2$, property $\subseteq 3$, state (parameter) $\subseteq 4$, indicator $\subseteq 5$, value$\}$.

D-10. The IU is single-point if the subset corresponding to the value is single-point and cannot be divided into parts.

D-11. The precision is associated with the value.

Each element of the IU is observed (identified, defined) based on signs. An IU has a hierarchy, does not allow for ambiguous interpretation and arbitrary application of terms. The presented system of terms is a universal model, can be used for calculating the states of objects of any nature. The structure of terms is shown in a diagram in [10, p. 91].

The structural approach also implies the search for and establishment of a more abstract (in relation to the researched one) umbrella term. In our opinion, the category of *intended use* is such a concept. Below is the substantiation.

The category of "intended use" as an object's property. The concept of intended use is large in scope, is more abstract than the concept of dependability. Let us note that the quality standards (ISO) were developed under the assumption of the intended use being the compliance of an object's characteristic with the requirements (GOST ISO 9000-2011: "Quality: the degree of compliance of the sum and the intrinsic characteristics with the requirements").

Russian standards prioritized the dependability concept, where the regulatory descriptions, definitions, such as "the ability to perform the required (specified) functions, (an object's) ability to function", "to function as and when required", "functional dependability", "parametric dependability", "requirements specified in the documentation" are simply generalized by the category of intended use. Such descriptions are none other than an indication of the property of an object's intended use. For instance, an object's *ability* to move in space is a property of intended use, not dependability.

If an automobile "is sitting in traffic" (the example given in [2]), is not intended to also be a helicopter or an airplane like in the 1965 movie Fantomas Unleashed, it is its intended use per the design, i.e. moving in a two-dimensional space. Therefore, an absolutely dependable automobile will sit in traffic "dependably" and motionlessly.

Thus, all the terminological searches in terms of dependability standardization demonstrate an unjustified reduction of the concept of intended use to the concept of dependability. **The introduction of the category of intended use solves the problems of terminology in the dependability theory.** The author suggests the following definition of intended use.

D-12. Intended use is the property of an object defined by the natural origin or designed application.

The property of natural origin: the intended use of "a pike who lives in the lake is to keep all fish awake".

This definition is introduced for a simple object. The intended use of a complex object may be considered as a combination of property elements. If we adopt the proposed point of view that the concept of intended use is a property, then all the derived concepts are states. In the context of this paper, such states include dependability, safety (security), risk, efficiency, etc.

The problem of alternative terminology in the dependability theory of technology. Given the above, let us present an example (model) of the development of an alternative dependability theory terminology. Only the basic definitions are suggested. This paper does not aim to completely rework the standard.

D-13. Dependability is a set of states as the measure of concordance with the intended use of an object. The alternative definitions are given below (Table 1).

The example of terminology development does not provide for analogous use of terms like "good state". We assume that terms related to events and processes are to be carefully examined in terms of the philological and logical aspects in order to establish clear distinctions. Thus, among other things, instead of the term "defect" the term "breakdown" should probably be used.

5. Conclusion

The evolution of the concept of technology dependability reflects the unsolved terminological problem in the dependability theory of technical objects. The problem of terminology largely consists in the ambiguous use and confusion of ontological terms. Deduction of such terms based on pseudophysical logic and introduction of the category of an object's intended use is the main result of this paper in

Table 1. Example of the development of an alternative terminology in the dependability theory of technology

GOST 27.002-2015	Alternative definitions
3.2 States	States of dependability
3.2.1 good state: The state of an object, in which it complies with all the requirements specified in the respective documentation	**Good state**: a state that complies with the intended use of the object subject to allowable damage.
3.2.2 faulty state: The state of an object, in which it does not comply with at least one of the requirements specified in the respective documentation	**Faulty state**: a state that does not comply with the intended use of the object due to defects.
3.2.3 up state: The state of an object, in which it is able to perform the required function	**Up state**: a state that complies with the intended use of the object.
3.2.4 down state: A state of an object, in which it is unable to perform at least one of the required functions due to reasons depending on it or due to preventive maintenance	**Down state**: a state that does not comply with the intended use of the object.
3.4 Failures, defects, damage	Events of disrupted dependability
3.4.1 failure: An event consisting in the disruption of an object's up state.	**Failure:** an event of disruption of an object's up state.
3.4.2 defect: Each individual non-compliance on an object with the requirements specified in the documentation	**Defect:** an event of disruption of an object's good state.
3.4.3 damage: An event consisting in the disruption of an object's good state under condition of retained up state.	**Damage:** an event of an object's disrupted good state under condition of retained up state.
3.5 Maintenance, restoration and repairs	Dependability restoration processes
3.5.2 Maintenance: A set of organizational actions and technical operations aimed at maintaining the operability (good state) of an object and reducing the probability of its failures in the course of intended use, storage and transportation.	**Maintenance**: the process aimed at maintaining the up and good state of an object.
3.5.5 recovery: A process and event consisting in the transition of an object from the down state into the up state.	**Recovery:** a process aimed at causing the transition of an object from the down state into the up state.
3.5.9 repairs: A set of technical operations and organizational actions aimed at recovering the good or up state of an object and restoration of the operating life of the object or its components.	**Repairs:** a process aimed at causing the transition of an object from the faulty state into the up state.

terms of the introduction of an alternative noncontroversial structure and content of dependability-related terms. The suggested approach is recommended to be used for revision of the existing standards.

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The author’s contribution

The author analyzed technology dependability standards. A verbal, lexical-grammatical and logical analysis of the concept of dependability was performed. A new alternative definition of dependability was proposed along with proposals as to the standard’s modification.

Conflict of interests

The author declares the absence of a conflict of interests.