Physics of Systems is a Postcybernetic Paradigm of Systemology

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ABSTRACT

Physics of Systems has proposed a new approach to cognition, understanding and explanation of open systems' complexity phenomenon. Birth of Physics of Systems is bound to general problem's decision of reconstructive analysis of natural humanitarian and technogenic systems under their empirical descriptions. This decision laid foundation of scientific knowledge about system-forming interactions and inner world of open systems. Analytical apparatus of scientific understanding and rational explanation has formed as a result of creation of open systems' language and system knowledge's qualitology. The becoming of the new paradigm has terminated after having solved the synthesis problem of scientific states reconstructions, states evolutions and emergent properties of open systems.
Physics of Systems researches open systems in natural scales and real complexity. Ideas and methods of Physics of Systems are embodied in informational technologies which provided regularity search, complexity reduction and reconstruction of the whole in open systems. Technologies of Physics of Systems automatically generate the scientifically proved knowledge out of data collected by empirical science.

Keywords: open systems, system knowledge, system reconstructions, ontological modeling, communicative modeling, states modeling.

1. INTRODUCTION

Ideas of Physics of Systems came into being in the 70-ies under effect of prof. A.A.Vavilov works and his disciples' works (*St. Petersburg State Electrotechnical University "LETI"*). These works dedicated to evolutionary synthesis were the first attempt of deep study of relations structures in dynamic systems [1].
Collaboration of scientific groups of prof. B.F. Fomin (*St.Petersburg State Electrotechnical University*) and of prof. V.V.Kalashnikov (*Institute of Systems Analysis, Russian Academy of Sciences, Moscow*) in the field of computer technologies of system modeling was an important step to Physics of Systems [2].
Large-scale studies of obstruction mechanisms of bronchi and lungs were being carried out under the direction of prof. G.B. Fedoseev (*Pavlov State Medical University of St. Petersburg*) and assisted in the origin of Physics of Systems. The statement of Physics of Systems idea is directly connected to the software package COMOD (*COnceptual MODelling*) which is created by prof. T.L. Kachanova (*St. Petersburg State Electrotechnical University*) and is designed for the study of physiological and pathogenetic obstruction mechanisms of bronchi and lungs.
In 1994 B.F. Fomin and T.L. Kachanova began systematic scientific development of the approach embodied in COMOD. To 1996 the methodological foundations, main definitions and key problems of Physics of Systems were defined [3-5].
In 2003 the project named "Physics of Systems" directed on creation and use of infrastructure and applications for production and handling of scientific system knowledge has formed. For this project's execution the consortium "Institute of Strategic Developments" was created. The authors, the developers of technologies and the participants of applied approbations of Physics of Systems formed the consortium membership.
Approbation was held in six directions: the computational toxicology, the ecological genetics, the system biology [6-8]; the theoretical medicine [9-11]; the solar-terrestrial physics [12-14]; safety [15]; the technological platforms of the generation of scientific system knowledge; the knowledge management.

2. BASIS OF NEW SYSTEMOLOGY PARADIGM

The trine of fundamental sciences (philosophy, physics and mathematics) serves as a base of systemology.
Philosophy is categorial and a priori in own grounds. It declares that general beginnings that express the main senses of the real world are on the basis of the essence. The aim of Philosophy is the creation of the complete system of principles and universal laws of the being.
Mathematics builds utmost abstract world of the universal symbolic constructions, creates ideal objects without basing on the empirical experience. Fundamental abstractions are the most important concepts of mathematics. They underline the base of strict mathematical methods to symbolic constructions of which the representations of particular sciences are finally being resolved into.
Physics cognizes general principles and regularities of the world organization in the process of concrete empirical study of the nature. Penetration into depths of the structure of the substance and the nature of interactions, the cognition of the essence of phenomena and the processes through discovery of the nature's fundamental laws is the object of physical studies, Fig.1.
Systemology is becoming one more fundamental generatrix of scientific knowledge. It creates special world of concepts that is the world of systems. Every system in this world sticks out as utmost common, universal in form, structurally comprehensive image. This image has it's own basis in the empirical experience, transfers the senses of both objects and phenomena of the reality, and is embodied in abstractive interpreted forms.

The problem of cognition of phenomena, processes and objects of the reality is the problem of complexity disclosure that is perceived as heterogeneity, multiquality, polyfundamentality, polymorphism and substantial pluralism.

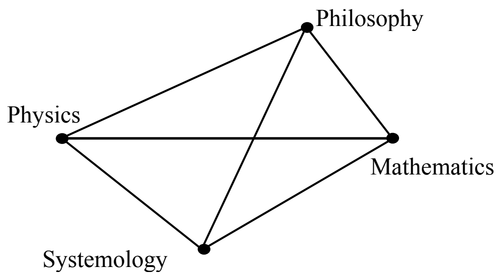

Fig. 1. Quaternary of fundamental sciences

The problem of complexity became the first cause of the system movement. Tasks of complexity reduction to simplicity and reconstruction of the complex unity define systemology content. The understanding of complexity of open systems in a new paradigm of systemology is being achieved through the concept "System". It is an initial and central concept in Physics of Systems.

3. DEFINITION OF THE SYSTEM IN PHYSICS OF SYSTEMS

The concept "System" is fundamental research's subject-matter and a product of cognitive activity which organizes the understanding of empirical facts through the comprehension of the senses of the nature of phenomena and the processes hidden in these facts. The initial idea of the system is the unity. Issue of the system's idea from the world of sense outwardly is related with the unity division and its manifestation in the reality through the set of the system's idea carriers. The carriers are the objects of the real world. Their states are accessible to empirical definition. Each state of the carrier serves as an image of one definite semantic cut of the system. Scientific understanding and explanation of the system's essence in all its semantic cuts are related with the definition of a great number of the carrier's all states, Fig. 2.

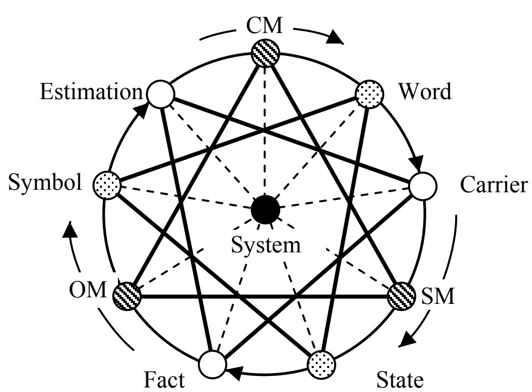

Fig. 2. Definition of concept "System":
OM – ontological modeling; CM – communicative modeling; SM – states modeling

At the system-wide knowledge's level the open system is represented by the triad "Symbol – Word – State". This triad conveys semantic organization, semantic activity and semantic forms of the concept "System".

Semantic organization (Symbol) discloses organization of the system's multiqualitative unity consisting of individual unities, which have it's own core, organized out of the unique initial elements (singlets).

Semantic activity (Word) is being manifested through the qualities and properties of all elements and all the parts of the system organization which are generating the language of the system which is able to convey disclosed and understood sense outwardly.

Semantic forms (State) denote and figure understandable sense of the system and define formal synthetic image (reconstruction) of the system's unity. This image is able to be embodied in multiple objects of the reality.

The triad "Symbol – Word – State" in real world has its reflection in the triad "Fact – Estimation – Carrier". This triad is engrained in the *observed reality (Fact)*, is in contact with reality through the objects *of reality (Carrier)* and establishes *measures (Estimation)* which are expressing ability of the fact to perceive and undertake the system's senses embodied in the carrier.

The triad "Symbol – Word – State" is connected with the triad "Fact – Estimation – Carrier" through the triad "OM (ontological modeling) – CM (communicative modeling) – SM (states modeling)". Given triad passes processes of cognition, understanding and figuration of the system's idea.

Ontological modeling defines *cognition process of the systems' essence*. It uses organization principles of the semantic world of the systems (*doctrinal model*), initiates and proves foundational concepts and representations about the system (*dialectical model*), applies cognition's scientific method of the systems' essence (*constructive-methodological model*) and embodies the disclosed system senses in the external abstract images (*symbolic model, signed model, system's portraits*). During cognition process the scientific-wide knowledge about the system arises [16-18].

System becomes an object of *understanding and explanation* as a result of the transformation of scientific-wide knowledge into the knowledge about all actual states of the system. Properties and qualities of the elements, parts and all the semantic system organization as a whole are being reflected in *words and concepts of* the *language* that are represented on the levels of the language semes, its lexical composition, denotative and connotative words meanings and syntagmatic associations [19, 20]. Communicative modeling supports application of the systems' language for scientific understanding and rational explanation of the knowledge. The combination of the system's states resulted from semantic world defines the system able to be actualized in the reality, in categories of value, quantity and order. The carrier of every such state in the world of fact is known. Through the carrier an image of the system in the real world arises. This image is given through the set of observed states that inherited qualitative-semantic organization of the system and are filled by quantitative values of measures and their subject attributes. Quality of the transformation of scientific-wide knowledge about the system into scientific knowledge about system's concrete states is being characterized by the measures of understanding. They serve as a basis for the states synthesis, and a tool of estimating the quality of empirical fact and the system-wide knowledge from a perspective of the synthesis completeness.

States modeling is an act of *system's figuration* when, as a result of it, the objects of the reality undertakes the senses of the system. The senses of the system are identified with the fact and they bring the system into a new manifestation form of unity and integrity of the system. This form is brought about by the general semantic organization. Reconstruction of the system's state is being created for every carrier instance.

Actual states are being defined strictly in an external form through the carrier and values of its measures. As a result of modeling, the system's states in the semantic world arise. Each observed state receives the definition of the inner form (scientific reconstruction), in which the state is being preset by the set of informative measures organized into the self-consistent semantic structure equipped with attributes expressing emergent properties and qualities of the state.

4. "INTELLECTUAL MACHINE"

The production of the scientific knowledge from the empirical descriptions of the open systems passes into six steps and three stages, Fig.3.

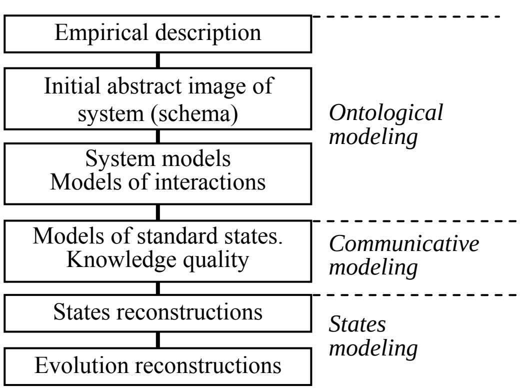

Fig. 3. Steps and stages of knowledge production

The ontological modeling produces the symbolized system-wide knowledge embodied in system models. The communicative modeling transforms system models into standard states' models determined by measures of understanding and estimating quality of the knowledge. The states' modeling creates scientific reconstructions of all the actual states of the system, of its states' evolution and the evolution of its emergent properties.

The Empirical description of the open systems is being created on the basis of data collected by the empirical science. Empirical description presets initial representation of the system. Operations defining its construction are following below: choice of the carrier (*isolation*); the carrier state description by the fixed parameters set (*entirety*); the definition of the carrier instances set (*representativity*).

The initial abstract image of the system (schema) arises on the base of its empirical description. It serves as the external manifestation of latent intrasystem mechanisms and processes, represents the system as the whole constructed by means of normative initial elements' integration (attributed binary relations between system's all parameters).

System models and models of interactions form the symbolized system-wide knowledge on the base of which the intrasystem mechanisms are being disclosed. Sets of system models and models of interaction are being received out of the initial abstract image of the system (schema). Each system model describes the all system in one of its *qualitative definiteness (locality)* that is formed by the distinctive mechanism of system-forming. Set of interactions' models defines all types of structural and behavioral invariants explaining a multi-qualitative system's unity.

The Models of standard states arise from the system models. Each system model begets four models of standard states. Each standard state of the system is being formed by the one unique intrasystem mechanism.

The Quality of the scientific system knowledge depends on entirety and correctness of this knowledge's expressiveness in external symbolized forms of the system models. For all the system models the objective integral quality ratings of sense-expressiveness in each separately taken model (*figuration, homogeneity and adequacy*) are installed.

All the actual system's states are represented in its initial empirical description. For the each actual state is being created its scientific reconstruction on the base of the system knowledge. This reconstruction is the formal model disclosing all intrasystem mechanisms in their interaction determining the given state of the system.

Scientific reconstructions arise as a result of synthesis of the system representing one whole in each actual state. In the capacity of system parts of this one whole concrete sets of standard states' models are represented. Each model of these sets discloses one characteristic aspect of the system's state. Each model has a structure the basis of which is a *core*. The core transfers an idea of the concrete state of object and carries itself a variability potential of this state.

Actual states of objects under observation in their empirical descriptions are ordered by times (or by other ordering parameter). The evolution reconstructions of the states of objects under analysis represent the formal models in which the set of reconstructions of the states of objects under analysis is regulated by time. These models formally describe the analysis object as a whole with its characteristic manifestations on the given time interval. Reconstructions of the evolution of states disclose the system properties of the object through *the evolution of the cores of models of the object states, actualization of system-forming mechanisms and set of attributes estimating a system function of the parameters*.

Attributes of the level of importance, mobility and meaning correspond with each parameter in reconstructions.

The *Importance attribute* characterizes the parameter as a necessary identification element of the object's concrete actual state. The *Attribute of mobility* estimates variability potential of the parameter in a given state. This potential can become reality in the future.

Actualization of each system-forming mechanism on the observation interval reveals the presence of the mechanism's all standard states, a sequence order, the frequency of occurrence and the manifestation strength of these states in evolution. *Actualization of the Mechanism* means actualization of corresponding model of the system's standard state. The *model's actualization* permits to define allowable intervals of concerted variability of the parameters in those points of the order parameters scale where the object states correspond to this model.

The sequence order, frequency of occurrence and the manifestation strength of states in the mechanism evolution are conditioned by joint action of all set of system-forming mechanisms which form each state of analysis object.

Consistency degree of all these mechanisms' action is being estimated by the *importance attribute*. The *attribute of mobility* measures a presence and inconsistency measure of mechanisms action.

Reconstruction of the evolution of states covers a set of models of the intrasystem mechanisms defining this evolution, begets the sets of attributes of both models and parameters forming the base for the rational explanation of the nature of the observed variability of the analysis objects.

5. FORMATS OF SYSTEM KNOWLEDGE

The scientific system knowledge which has formats of models, emergent properties' attributes, classes of states and classes definitions is a result of technologies application of Physics of Systems.

Knowledge in formats of models:

– system-forming mechanisms that are preset by invariant relations structures and are generating standards of the states of the system with characteristic domains of parameters variability;

– intrasystem interactions that express a coherence property of system-forming mechanisms and disclose a potentials of states variability;

– objects states of analysis with normative characteristics of these states;

– analysis object's states evolution which describes change regularities of states over the order parameters.

The Knowledge in formats of emergent properties' attributes is the knowledge about parameters being perceived as empirical fact, the system sense's carrier, the moment of understanding and then the explanation of observed states of analysis object and the states' evolution. The knowledge about every parameter is disclosed through its ability:

– to manifest in external forms of values variability the multiqualitative essence of the system;

– to transfer outwardly the system's essence as a heterogeneous unity of the whole;

– to play certain system roles in models of standard states;

– to have characteristic semantic activity in mechanisms of intrasystem interactions;

– to possess system mission in every separately taken model of standard state;

– to implement semantic quantization of the observed values of quantities;

– to be necessary element of both state's semantic definition of analysis object and evolution regularity of this object's states.

System knowledge in formats of objects states' classes and classes' definitions:

– the classification of the observed states of analysis' object over set of its qualities that are disclosed in system models of standard states;

– the rules, defining for the each class of the states the domains borders in limits of which the actual states are being estimated over manifestation degree of quality in them, which characterizes this class.

Scientific system knowledge in such formats explains every analysis object in each its separately taken actual state, in each quality typical in this object in this state with understood manifestation degree of given quality.

6. RELIABILITY OF THE SYSTEM KNOWLEDGE

The scientific method of Physics of Systems provides generation of reliable system knowledge. Reliability is ensured by objectivity, system level and verification level of knowledge.

The Objectivity of knowledge is conditioned by resting on empirical fact as an exclusive source of objective information about reality objects. System knowledge in all its formats is being automatically generated out of empirical data by technologies of Physics of Systems without any addressing to expert knowledge.

The System level of knowledge is guaranteed by scientific method of Physics of Systems, when analysis object on each step of knowledge generation is considered as the system taken as the one whole or as the all whole in conditions of the part. That conditions a reliable transfer of emergent properties of researched systems by elements of system knowledge.

Physics of Systems overcomes open systems' complexity with that entirety degree as far as the complexity is initially manifested in empirical descriptions. Degree of complexity disclosure is being estimated by *quality (entirety, finality)* of generated knowledge.

Formal system models whose adequacy is being checked by scientifically proved *procedures of verification* are the base of system knowledge.

7. TECHNOLOGIES OF PHYSICS OF SYSTEMS

"Intellectual machine" of Physics of System is embodied in technologies of its analytical core:

– *Technology of the System Reconstructions (Ontological modeling)* generates, organizes, figures and represents intellectual resource (the base of the scientific system knowledge);

– *Technology of the System Examination (Communicative modeling)* performs semantic analysis, explanation and determination of intellectual resource's elements and estimates the received scientific system knowledge from positions of its reliability, entirety, finality, applicability, significance and actuality;

– *Technology of the System Design (Modeling of states)* synthesizes adequate verified models of both states and states' evolution of the system, investigates emergent properties of the system, generates, organizes, figures and configures problems' system solutions;

– *Technology of Empirical Contexts' Formation* transforms system's multi-purpose vision into informational resource of scientific knowledge's generation;

– *Technology of Solutions Behavior Generation* offers high-automated interface for standard environments of computer simulation, "animates" system solutions and creates detailed behavioral portraits;

– *Technology of Analytical and Graphic Solutions Representation* supports high-automated interface for standard environments of solution figuration.

By Technologies of Analytical Core following is being provide:

– producing and sufficiency expertise of *informational resources* of completed knowledge's generation about open systems;

– informational resources' defects educing, requirements' forming towards management and design of informational monitorings of systems and problems;

– *intellectual resources'* generation (*system knowledge's bases*) for scientific understanding and rational complexity explanation of open systems;
– intellectual resources' expertise on actuality, adaptability, and sufficiency for scientific understanding and rational explanation of properties, states and evolution of open systems, and getting completed solutions of concrete target problems.
Analytical Core's operative technologies of Physics of Systems marked a beginning:
– for mastering huge volume of accumulated empirical data about natural, humanitarian and technogenic systems on practice and for bases creation of reliable scientific knowledge about open systems;
– for generation of overall solutions over open systems' complex problems on the basis of scientific knowledge;
– for creation of technological *R&D* platforms based on knowledge;
– for elimination of interdisciplinary interaction's technological barriers on the basis of the wide usage of open systems' language and system knowledge's qualitology.
Analytical Core's technological base of Physics of Systems is being evolved. In a complete kind the analytical core should be including nine technologies in which the Physics of Systems will receive its full embodiment, Tab. 1, Fig. 4.

Table 1. Technologies of Analytical Core: composition, properties, readiness and perspective of improvements.

Technologies	Leadership, independence	Imrovements		
		2009	2010	2011
Technology of System Reconstructions	Leading independent technologies	[5]	[5]	[5]
Technology of System Examination		[5]	[5]	[5]
Technology of System Design		[4]	[5]	[5]
Technology of Empirical Contexts' Formation	At right actions in 2010-2011 the leadership and independence of technologies can be achieved.	[4]	[4]	[5]
Technology of Problems Vision Forming		[3]	[3]	[4]
Technology of Subject Examination		[3]	[3]	[4]
Technology of Laws Figuration		[3]	[3]	[4]
Technology of Solutions Behavior Generation	Dependent technologies. Dependence is insignificant.	[4]	[5]	[5]
Technology of Analytical and Graphic Solutions Representation		[4]	[5]	[5]
[3] – breadboard model is in laboratory medium, [4] – prototype is in real medium, [5] – ready-to-operate				

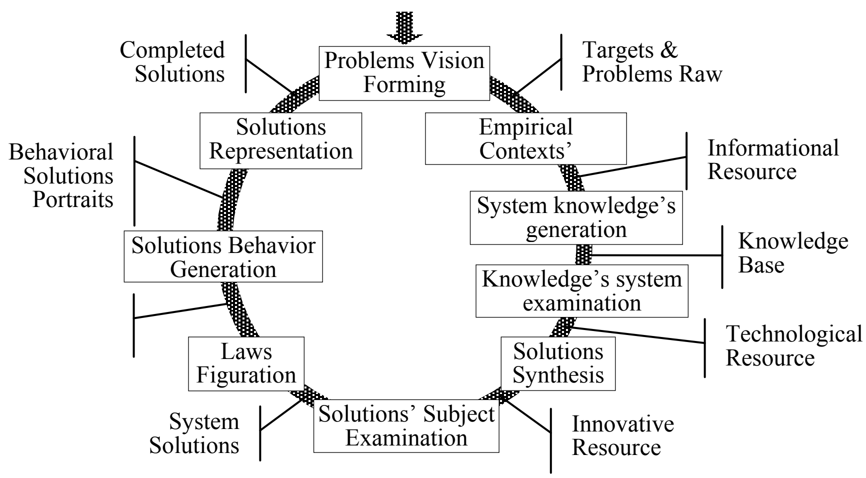

Fig. 4. Technological cycle of production of system knowledge and system problems' solving on the base of knowledge

8. CONCLUSION

Physics of System is developed by the one scientific group. Consortium "Institute of Strategic Developments" currently works at evolvement and application of Physics of Systems. Its main efforts are directed onto:
– the advancement of Physics of System into scientific community, education and business in the quality of a new paradigm of systemology;
– technologies realization of Physics of Systems in socially significant projects of knowledge generation on the base of data about natural, humanitarian and technogenic systems;
– the creation of adequate infrastructure and effective software for automatic generation of complete, finalized, reliable and objective knowledge about open systems;
– the deep scientific understanding and rational explanation of received knowledge;
– the support of complete life cycle of scientific knowledge about open systems acting as the new science intensive market product.
– the commercialization of the scientific system knowledge.

On the basis of methods and technologies of Physics of Systems more than 60 applied projects in foreground knowledge domains are executed.

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