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From the System Analysis of Applied Geometry Methods toward the Structure of the Ukrainian Geometrical School[1]

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Abstract. The historical development, the internal structure and the information contents of the Ukrainian School of Applied Geometry are analysed using methods from the theory of organizations, from social psychology, and modern management. This is the base for estimating tendecies of its future development and determining operative and strategic targets for this scientific area under new market conditions.

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1. Introduction

The problem of viability and urgency of graphic disciplines in an epoch of a total computerization is global. Besides the modern graphic disciplines undergo essential internal transformations. In a complex this causes changes in subject and methodical bases for various graphic disciplines, washing out a methodological nucleus of the science. Thus, ideologically harmonious classical Descriptive Geometry will be transformed to a great number of forms of synthetic[2] disciplines such as Applied Geometry, geometrical modeling, computing geometry, computational geometry etc. Various approaches to an actualization of modern graphic disciplines are available: from a change of paradigm at an educational level [4] to the inclusion of a given group of sciences in a certain superstructure [1].

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[2]In this respect *synthetic* means the type of a science which is created as a synthesis of the theories of some canonized (= traditional) sciences.

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From our point of view, some aspects of the given problem can be solved by bringing in methods of the analysis of complex systems. As a complex system it is consistently necessary to consider:

- methods of Applied Geometry;
- the complete information contents of the discipline;
- Applied Geometry as a social-technical system.

The *first level* of such consideration has been submitted in [6]. The system consideration of *modeling methods* has allowed to solve a problem of methods hierarchy and to define a method which is rational for solving some theoretical and practical tasks. Besides the operations above, a great number of modeling methods allow to generate special methods, ways and algorithms of their realization with the beforehand given conditions (in particular, previously unknown methods).

The *second level* of consideration enables to investigate the complete internal structure of Applied Geometry, to look after its transformations in time. However in this analysis the main topic is the research of boundary interaction of the given discipline with other scientific areas, which is the important aspect of its *viability*.

The *third (general) level* of consideration of the system "Applied Geometry" is based on methods of the theory of organizations, social psychology, and modern management. The approach allows to offer a rational form for the organizational existence of the given scientific area under a real economic sphere.

In the present article the last two levels of research of the problem are discussed. Let's notice that the research is executed on the example of the Ukrainian school of Applied Geometry, which has some specific features in structure and functioning.

2. Information analysis of the subject-substantial component of the system "Applied Geometry"

The formation and the development of Applied Geometry, evolved on the base of Descriptive Geometry, representing an applied discipline from the moment of occurrence on, has been taking place within a semi-centennial historical period. It is characteristic by the growth of interdisciplinary connections, rough expansion of the application spheres, increase of industrial orders for research development, and by the introduction of computer technologies [7].

Applied tasks (instead of the theoretical researches with search of introductions) have becoming the center of science. The peculiarity of the process of a research service for an applied task has required to keep various methods for creating a complex of objects and process models (appropriating to various design stages and the "know-how") both maintenance of interrelation of models and ways of their reorder. It has caused both a development of its own geometrical base, and an attraction and adaptation of methods of adjacent disciplines from the application sphere. Thus in various applied areas there were invariant geometrical models and methods which has caused their spilling over from area to area through Applied Geometry. It has emerged most brightly in design methods for surfaces showing up at technical forms like in shipbuilding, motor-car construction, aircraft construction, at designing casing in architecture, labour bodies and machines etc.

Now there is time to bring up the following question: *How much is the development of Applied Geometry with its features comparable with the general laws for science development and what tendencies of development can be expected.*

From the information point of view [2] the system "science" may be presented as a *circulation of three information flows* (Fig. 1):

F_o — actual material, results of research;

M_o — methods and techniques for processing the material inherent for the given science;

C_o — ideas, concepts and theories of the given science (methodology).

Let us notice that the structure, role and the actual scope of each information flow are essentially changed at various stages of the scientific course development. As M_o and C_o constitute an actually theoretical nucleus of science, the viability and objective importance of the system depends on the quality of these elements. A. Einstein [3] offered *two precise criteria for a "good" theory:*

- *the external justification and*
- *scientific perfection.*

Let us try to look after the transformation from classical Descriptive Geometry to a modern applied one on the basis of the information model [2].

The examined scientific course S_o, taken separately (dash-dotted area of Fig. 1), affects on the object Ob*o* by noted information flows. For classical geometry such objects are the graphically submitted samples of physical objects. Though the subject domain of the science is extremely various, Descriptive Geometry does not leave the framework of its own methodological and methodical opportunities. The flows I'_o (F'_o, M'_o, C'_o) represent the corrected knowledge which is filling up the system S_o. The sixties are considered as a stage of canonization in science [3]. In this period the methodological and methodical means of Descriptive Geometry practically were completely revealed. At this time the conceptual system of Descriptive Geometry was determined by areas like the theory of mappings, including the theory of shadows, auxiliary views, generation and transformation of objects, e.g., curves and surfaces, and their application, methods for solving metrical problems [7]. Thus, M_o and C_o got the form of a stable (initial) theory, making S_o (examined separately) according to the definition above to a "good" theory. The results of the legal "fixing" as a scientific course was an increasing number of specialized councils on Descriptive Geometry, the foundation of a regular edition for thematic scientific publications in these years in USSR, including the Ukraine.

The key moment for the transformation from the detached system S_o into a synthetic one was the *activation of interscientific interaction* by the application of methods and theories S_o (in Fig. 1 — information flow I_{op} from the system S_o to the object Ob_p of the system S_p), not for traditionally operating with graphically presented images, but for the creation, processing and transformation of geometrical models of concrete technical objects. At this time the appearance of the terms *"geometrical model", "modeling", "forming"* etc. in the conceptual instrument of science was symptomatic. However, Ob_p is a traditional object of research of its own canonized scientific area S_p (building, mechanical engineering, air science, agriculture). And so scientific results I_p as new actual materials and as methods borrowed from S_o and adapted by S_p priority assimilates exactly by the system S_p. Whereas the actual inverse flow I_{po}, filling up the system S_o, is frequently ignored by "the external observer" S_p. Further there is an avalanche search for practical applications of the theories and methods S_o in various subject domains and counter orders of science. Then Descriptive Geometry in essence (and conceptually) became Applied Geometry. The primary demonstration of opportunities S_o at a new technological level became typical at most "geometrizing" aircraft construction and shipbuilding, while the application of classical Descriptive Geometry methods was traditional

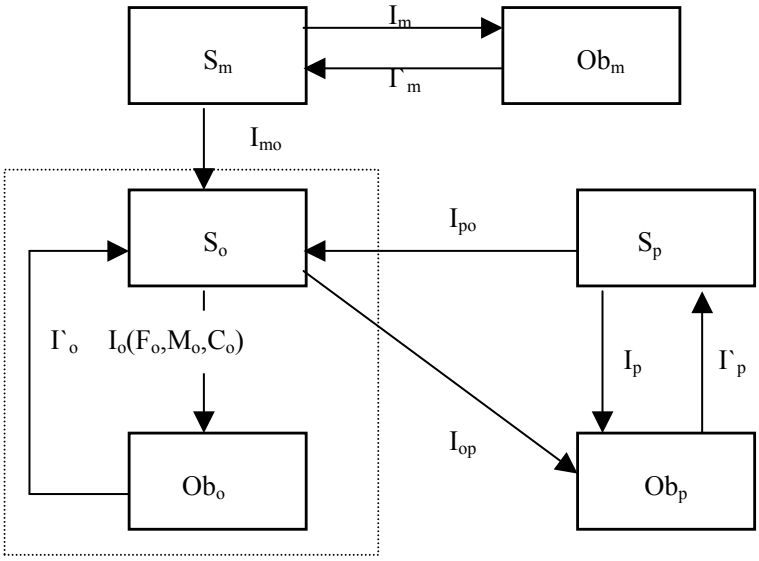

Figure 1: Traditional interaction of Descriptive Geometry with mathematical and engineering sciences

in earlier time.

The inverse information flows such as I_{po} essentially change the structure of the system S_o and result in a redistribution of the role and the substantial part of the flows I_o. The accumulation of the information F_o is observed at a certain crisis of theoretical assets M_o and C_o. In this connection the system S_o inevitably enters to an interaction with the block of mathematical computing sciences S_m (Fig. 2). The system S_o adapts and accumulates methods and the theories S_m (flow I_{mo}) in the theoretical nucleus (the constructive theories of nonlinear mappings, surfaces of higher order, linear manifolds, multidimensional spaces etc. are created). However from the "external" point of view, the system S_m is represented as applied adaptation of the well-known mathematical theories and, thus, the conceptual theoretical importance of results is ignored. It is necessary to pay attention to the information flow I_{om}, which recently is shown as borrowing visual geometrical methods by "pure" sciences (theory of singularities, qualitative analysis of dynamic systems, crystallography, topology). Nevertheless, the inclusion of methods (being important for S_m) to a theory of Applied Geometry is seldom approved by the S_m experts.

In Fig. 2 the important information flows I_{os}, I_{so}, I_{ps}, I_{sp} are also displayed. These flows determine the joint research of an object Ob_s which is new or close to the sciences S_o and S_p (as the second system can be S_m). *"... The experience got by sciences as a result of such interaction, quite often makes possible and necessary the acts of differentiation, separation of the complex and specialized disciplines"* [3]. In our case a typical example is the formation of computer drawing (S_s) as a discipline synthetic in relation to Applied Geometry and computer science.

One of the criteria for rating the possible expansion of Applied Geometry spheres of influence is the precise definition of sciences, which may be *application domains, adjacent, synthetic* and *assimilated* in relation to Applied Geometry.

1. In our case it is possible to consider the list of *application domains* as practically boundless because the geometrical methods are utterly invariant and many objects, phenomena and processes are of geometric nature.

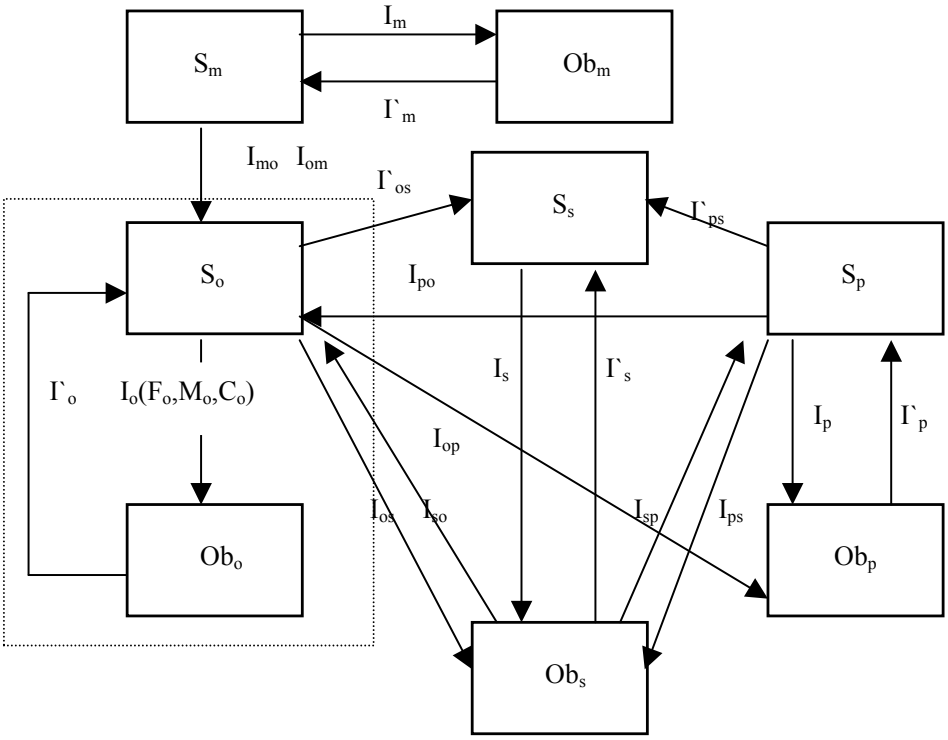

Figure 2: Transformation of Descriptive Geometry in Applied Geometry

2. Science, *adjacent* to Applied Geometry from the information point of view is any area with the established flow $I_{op}(S_o \rightarrow Ob_p)$, i.e., in case of a regular use of methodical means S_o for the decision of scientific tasks on objects S_p. As examples of adjacent disciplines one can consider building mechanics, architecture of spatial systems, building physics, shipbuilding, aircraft construction and mechanical engineering concerning the use of curvilinear forms etc.
3. The *synthetic scientific area* has "share holding" from S_o in own methodical and methodological maintenance solid alongside with other methods and theories. This is typical for such an area. It is computer drawing and, obviously, pattern recognition, graphic design, etc.
4. As a rule the *assimilation*, as unilateral confluence, occurs at the penetration of theoretical bases S_o in the scientific area, which has lost the attributes of a vanguard. The illustration is the revival of constructive-synthetic methods in Applied Geometry, which send on the background in modern algebraic geometry since that time.

It is natural, there is an essential share of subjectivity included in the given ratings executed by participants of the "uniting" processes of item 3 and 4. Nevertheless, the given differentiation demands maintenance of reasonable rules of interscientific interaction, in particular in the aspiration of artificial transformation from an adjacent science to a synthetic one at unreasonable penetration into the usual spheres of influence.

Thus the information analysis of some processes, typical for Applied Geometry under modern conditions, allows to make the following *conclusions.*

1. A detached, theoretically well-caused system (Descriptive Geometry) is transformed into a synthetic discipline (Applied Geometry, geometrical modeling, computing geometry etc.), acting by the constructive-evident converter of methods from "pure" sciences S_m

during modeling objects, phenomena and processes into various subject domains S_p.

2. During this transformation the value of information components F_o, M_o, C_o of the system S_o has changed: in intensity and breadth F_o the flow M_o is also characterized by a significant variety at weak order. The structure of a flow C_o is not practically revealed. It is possible to speak, that in a modern way C_o is the multitude of the constructive-applied theories, and M_o is a complex of adapted means S_m and is a function of the demands sum for tasks on a multitude Ob_p.
3. The modern expansion of the application domain S_o mainly occurs as a result of demands I_{op}, I_{os}, I_{om} going from S_o. Whereas for canonizing science, recognized from the outside, the reverse directions of demands are typical.
4. At absence of the well-caused theoretical nucleus and, in particular, of an externally acceptable definition of a methodological component C_o, the perception of the synthetic system S_o is inadequate to its real importance and potential opportunities. More rigidly: there is absent a methodological substantiation of existence inevitability of the area S_o in transition S_m — Ob_p satisfying both theorists S_m and engineers S_p.
5. Existence and role for S_o synthetic for S_o and adjacent subject domains S_s will be determined proceeding from a degree of conformity of the contents of information flows I_{so} to the system S_o. Apparently, it is wrongfully an artificial expansion I_{so}, as the last one (besides of interdisciplinary conflicts) leads to amorphism of the dim theoretical nucleus S_o and, really, to a decrease of the objective authority of an scientific area.

Hence, as a result of the system science-of-science analysis it is possible to state: For a stable perspective development, for "the external justification" and achieving "internal perfection" of a scientific direction, for the transition from a scientific school to a vanguard level it is necessary:

- *to prove, to allocate and to realize* practically modern conceptual system of Applied Geometry basing on constructibility and presentation as the integral properties of all methods M_o in the system S_o (structural-visual modeling of object, phenomena and process as methodological base of science);
- *to reveal* place and role of any M_o in the system S_o;
- *to establish* interrelations of various M_o with Ob_o, Ob_p, Ob_s;
- *to strengthen* the penetration of constructive-visual methods of S_o in areas of "pure" sciences;
- *to weight* rating and to prove expediency of an establishment of own and general spheres of influence at interscientific interaction, in particular, with adjacent scientific disciplines.

3. Applied Geometry: Organization theory positions

From the viewpoint of organization theory and sociology [5] the consideration circuit of a scientific school is represented in the following way (Fig. 3):

Applied Geometry as the organization represents an objective and spatially dispersed synthetic structure with the following peculiarity (Fig. 4):

1. A potentially boundless area of appendices of the system "Applied Geometry" from the scientific-practical point of view. Scope sphere of these areas and accumulation of

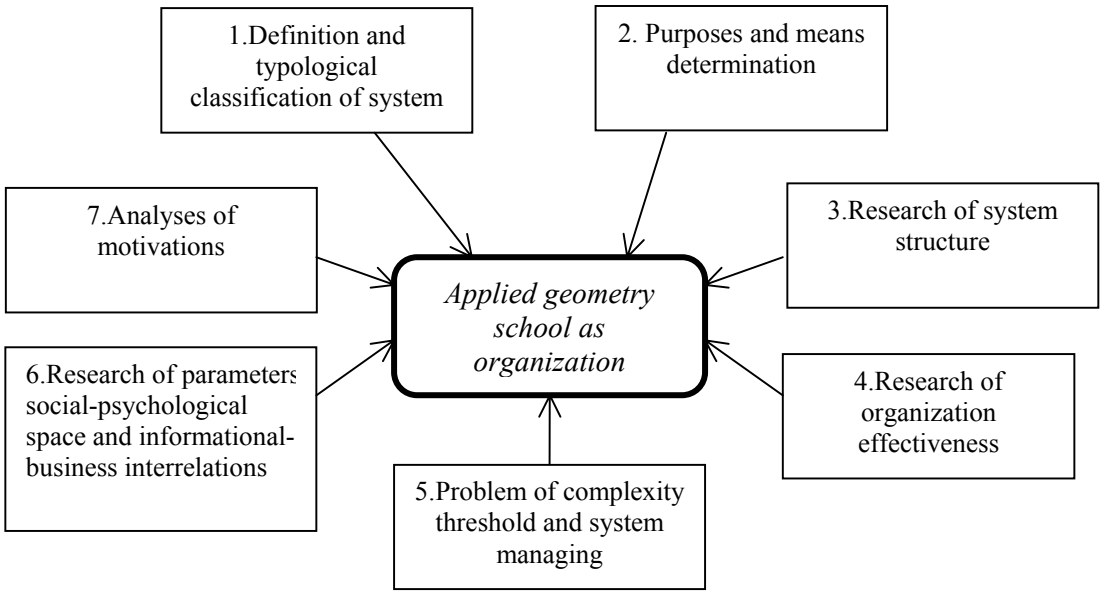

Figure 3: The consideration circuit of a scientific school

results develop uncontrollably to the inclusion into the structure of adjacent sciences system.

2. Weak definiteness of a system theoretical nucleus recognized from outside.
3. Absence (down to the creation of the Ukrainian Association on Applied Geometry (UAGG) in 1999) of a scientific-administrative branch, carrying out protective functions in interaction with an environment. In Ukraine the Applied Geometry has grown from Descriptive Geometry, which historically had not a protective administrative arrangement.
4. Specific collective management (regulation) through institutions, which are not intended for management: the specialized council, an editorial board for the periodical "Applied geometry and engineering graphics" etc.
5. Absence of traditional hierarchy of management in the presence of the pronounced leader with conflict-free delegated powers. The positive parameters of social-psychological space are typical for the system.

The interrelation of a network (or Mono-Specialized and dispersed Elements (MSE) forming it geographically and objective) with the basic structural components of a sociological system is shown in Fig. 4.

Let us notice that

1) the criterion functions of a network are realized at the level MSE, instead of the system level as a whole: existing actually, the network functionally does not work.
2) in the given circuit there is no controlled system of flux-distribution of internal (the geometrical novelty) and external (commodity) scientific product.
3) The established parity of functions and role relations is not a systems' attribute.
4) At first sight the level of development can be determined highly enough. However if we take into account the stand-alone character of maintenance of its stability and horizontality of development, the definition is problematic. It is available the contradiction between dynamism and system extensiveness of the organization development. So, the

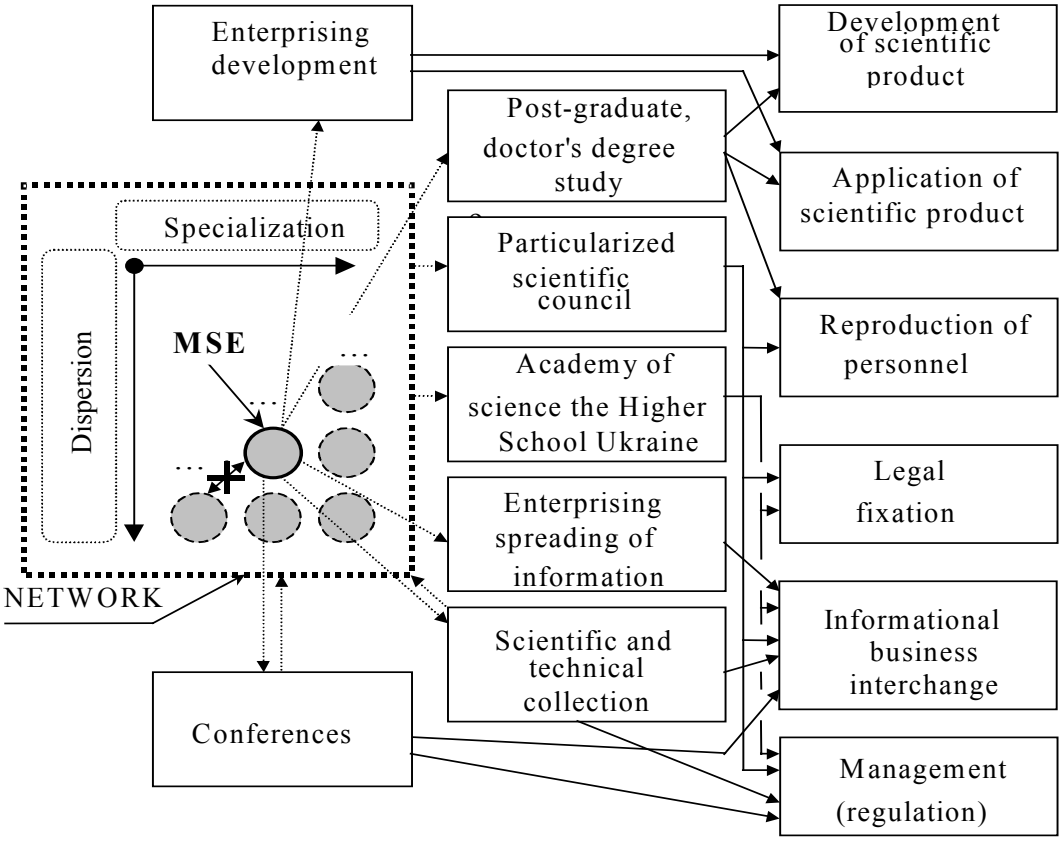

Figure 4: Applied Geometry in Ukraine as an organization
(the real condition before 1999)

examined system is powerful in objective sense, but it is not structurally predetermined. It specifies on potential internal conflictness of the system.

5) A problem of complexity. The system has reached the threshold of necessary complexity when its further development can be considered progressive only in a case of hipping its structures in a regulator component and realizing the whole complex of organizational-technical actions connected to it.

6) As the basis of such hipping (as a first approximation) it is necessary to consider the establishment of a legal person representing Applied Geometry in the external community. It will be an independent public organization with some regulating, protective, information, sponsor's and other functions.
Remark: Such organization should not be considered as a "pyramid" of management above existing system: network structures do not essentially accept vertical command methods of management.

7) The complex of reorganization in systems' technostructure should be constructed to compensate a potential transition to work under the conditions of a developed market. It is actual, as the examined scientific area is predisposed to self-disintegration.

It is rational to use the appropriate theories and modern approaches of management theory (including the economic type) by their extrapolation onto a specific scientific area.

From the viewpoint of modern management the school of Applied Geometry (under present conditions) represents the enterprise of a network structure with divisional specializa-

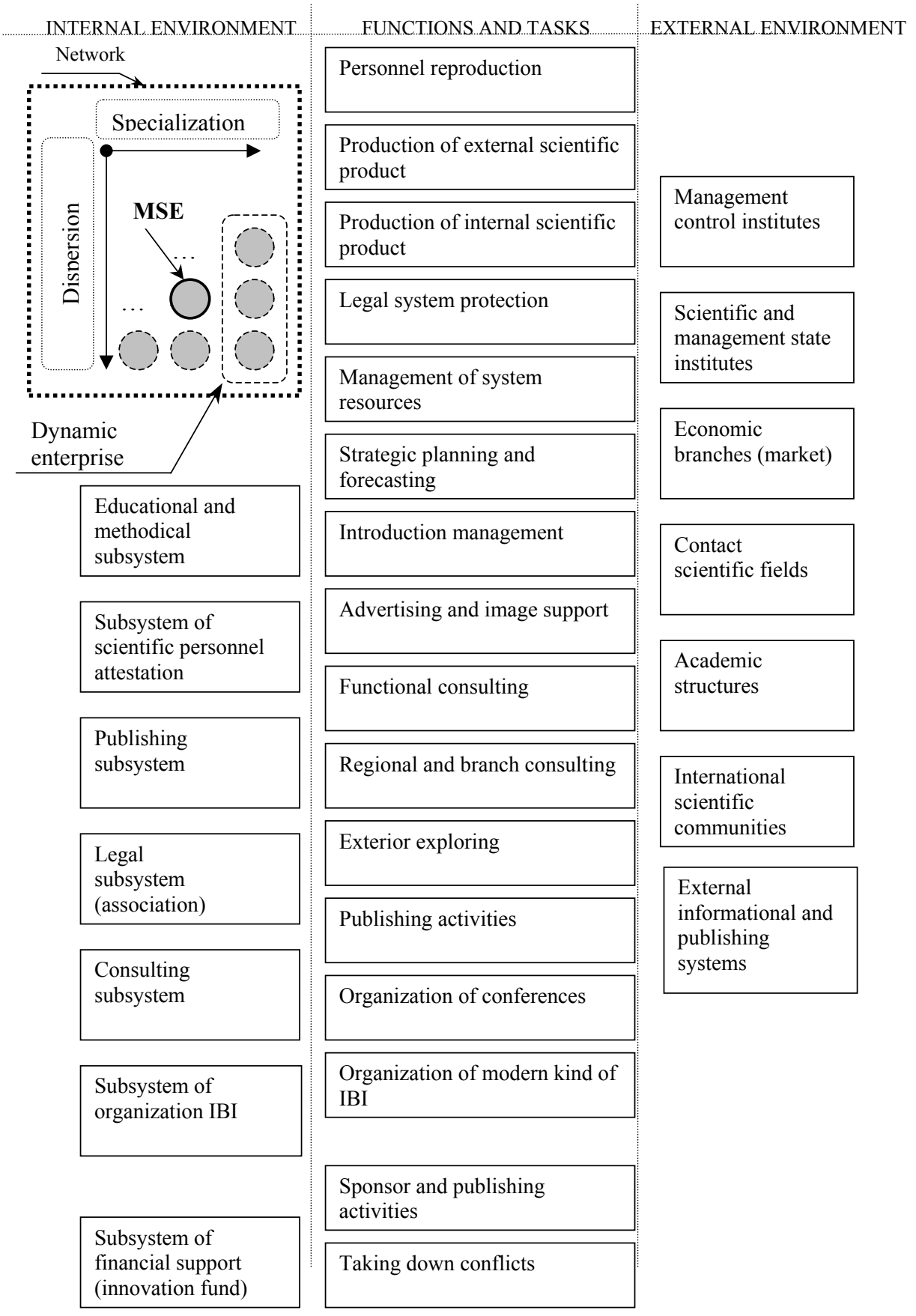

Figure 5: Applied Geometry as an organization (planned structure)

tion (the external scientific product is created inside only MSE, as a rule). Another opportunity of existence of the network enterprises is functional or matrix specialization when the product is made consistently by a circuit of several MSE. Opportunities of creating a really collective scientific product in a network consist in functional specialization.

The *strategic purpose* of the functioning of system "Applied Geometry" is the production and introduction of a scientific product in the geometrical modeling area, and also personnel reproduction and system expansion by its complete, mobile, failure-safe, conflict-free development under market conditions.

The *perspective purposes* of system functioning are

- achieving the academic status;
- a wide external recognition by the scientific community and contact market segments;
- a collective entry of the system in the international scientific communities;
- an introduction and management of the market of development introductions;
- a maintenance of the balanced policy of social protection of system subjects, first of all, experts and teachers.

The *operative purposes* of system functioning are the realization of a complex of organizational-technical actions on re-comprehend concepts, re-structuring and re-engineering systems for maintenance of achievement strategic and perspective purposes.

Tactical means of achievement of the specified purposes are using a system real condition as a base forming element of re-structuring; development of a specific system of control by knowledge, orientation of operative actions to a perspective condition of the market and the external scientific environment.

So, the contents of *re-structuring the system:*

- creation harmonious technostructure, as much as possible "adjusted" on specificity of construction and functioning of a network;
- basic functions redistribution between subjects of a network and common network subsystems;
- construction of a subsystem of legal fixing of representation and protective functions;
- organization of network "units" — the regional centres of created public organization;
- creation of the versatile consulting centre for research and managements of the introduction market, realization of functional consulting, management of a informational-business exchange etc.
- creation of the organization dependent on a legal subsystem which are carrying out financial support of system activity (fund);
- organization of advertising and image activity supporting system culture, providing propagation of traditions, experience, advertising of development etc.;
- reorganization of publishing: sponsoring of collections editions, proceeding of conferences; funding of the collection of articles on adjacent subjects;
- technical reorganization of a network: creation of regional internet centres, realization of Net-conferences etc.
- creation and realization of social support mechanisms for members of the organization, sponsoring of development, support of veterans etc.

Re-engineering of system:

- transition to the creation of a linear-functional development: using network specificity, including external experts;

- introduction and an effective use of new forms IBI;
- realization of a complex of managing and regular influences;
- development of recommendations on flux-distribution information and personnel resources in system (functional consulting);
- creation of associations for the decision at operative and strategic problems;
- intensification and stimulation of development on the theory and methodology of Applied Geometry, development in perspective market segments, the development supporting of "aggression upwards" — appendices of constructive-visual methods of Applied geometry in "pure" both natural sciences and nonconventional areas for system;
- active regulation and sponsor's activity in publishing area, and also at the organization of conferences;
- active realization advertising and image activity, in particular, in the academic circles and on perspective market segments.

The realization of re-structuring and re-engineering tasks has to be done step by step.

From the moment of beginning the practical realization of the offered system transformations at the Ukrainian school of Applied Geometry the Ukrainian Association on Applied Geometry (1999) was created, new scientific collections ("The industrial art and design" – 2001 and "Geometrical and computer modeling" – 2002) are founded. The association opens representations at the enterprises, sponsors editions of textbooks on graphic disciplines, and renders the address help to veterans.

The above-mentioned reasons are only provisional, in our opinion, the proved circuit of actions for the transition of the Ukrainian school of Applied Geometry to functioning at a new organizational level under new market conditions.

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