The concept of creating perspective technological paradigm of formation (development) of the underground space on the basis of the leading development of new approaches in construction geotechnology and geotechnics. Premises and basic provisions (part 1)

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Abstract. The article presents some reasons for the lagging of domestic mining engineering from foreign competitors, substantiates the need to form a new promising technological paradigm in the field of formation and development of underground space. A new systematic approach to the development of geotechnics and geotechnologies is proposed, which allows for creation of prerequisites for formation of a new technological structure and Russia's breakthrough into leading positions in the field of geotechnology and mining engineering.

The development of mining machines has long been on an extensive path, i.e. the increase in performance is achieved mainly due to the increase in power and weight and size characteristics [1, 2], with no significant breakthrough in the technical level. There is a noticeable lag from advanced industries, for example, from aircraft manufacturing. And this is typical not only for the Russian industry, but is a worldwide trend.

Technical characteristics of the aircraft are dramatically increased if weight and size characteristics are maintained or even if they are reduced. Aircraft designed with an interval of 25 years can not be confused during the arrangement by age (figure 1).

The growth of the technical level of mining machines, of course, is also there, but, alas, it cannot be compared to that of airplanes. Often, only a specialist can determine the age of a tunneling machine (figure 2).
There was a need to create a new technological paradigm in the mining engineering [3]. And while creating a new paradigm one should take into account the experience of other, more dynamically developing industries.

Let's consider the approaches and solutions used, in particular, in aircraft construction and shipbuilding. As is known, in these areas, the results of those studies are used, which are based on the process of studying the motion of a solid body in air and water, respectively.

Tables 1 and 2 present the existing infrastructure for tracking the movement of a solid body in various environments.

**Table 1. Infrastructure of tracking the movement of a solid in air and liquid environments.**

| Environment | Apparatus in the environment | Propeller | Mechanical engineering industry | Science of support | Test center |
|-------------|------------------------------|-----------|--------------------------------|--------------------|-------------|
| Aero        | Airplane, helicopter, etc.   | Propeller carrying screw (interaction with the environment) | Aircraft, helicopter engineering, rocket science | Aerodynamics of aircraft | Flight test center |
Table 2. Infrastructure of tracking the movement of a solid in a solid environment (geoenvironment).

| Condition | Apparatus in the environment | Propeller | Mechanical engineering industry | Science of support | Test center |
|-----------|------------------------------|-----------|----------------------------------|--------------------|------------|
| The status quo | Construction machines adapted to work in underground conditions | Wheel throw, caterpillar throw (interaction only at the contact of environments) | Mining machine engineering | absent | absent |
| Proposition | Geokhod | Helical blade (interaction with the environment) | Geokhog engineering | The study of the forces arising on the surface of a solid moving in a solid environment | Underground test center |

The aircraft industry is the most demonstrative. Originating at the turn of the last century and the past centuries, the industry in just over a hundred years has gone a long way from the first airplanes to modern airliners, helicopters and flying robots. Figure 3 conventionally shows the technological structure in the aircraft industry, and this structure was formed in the USSR at the turn of the 20s, 30s of the last century under difficult conditions of industry collapse, when the country was under technological and economic blockade, or in our time – under sanctions.

Technological structure in the aircraft industry has stood the test of time: made a great contribution to the creation of the “red” air fleet, winning the war, creating jet aircraft and, despite the difficult economic situation in the country in the 90s, kept it at the forefront in the world in the field of aircraft manufacturing.

The key elements (structures) of the technological paradigm in the aircraft industry are:
   – Aerodynamics of aircraft [4, 5]. Fundamental science, studying the forces arising on the surface of a solid body moving in air environment.
   – Aircraft [7, 8].

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   – Aircraft [7, 8].
1) Scientific discipline related to the design and construction of aircraft.
2) An aircraft manufacturing industry.

Aircraft (aircraft industry) at one time initiated the need for the industrialization of the country, and also became one of the main consumers of the created components of mechanical engineering: materials; bearings, mechanisms, etc.

– Research institutes (centers) of flight tests [9, 10]. The emergence of new professions: test pilot, test engineer, new methods and techniques

1) Conducting full-scale ground and flight tests of aircraft and their systems.
2) Participation in the development and upgrading of aircraft at all stages of its life cycle.
3) The introduction of tested aircraft and their systems in civil and military aviation.

**Project and technological tools**

1) Designing airports, etc.
2) Navigation provision, etc.
3) Staff training.
4) Creating and improving the regulatory framework.
5) Ensuring the safety of flights and operation of aircraft.

In the aggregate, the elements (structures) of the technological structure in the aircraft industry form a certain amount of knowledge – a paradigm of knowledge of the technological structure. In figure 3, the paradigm is conditionally represented as a volume of a tetrahedron.

With any change (increase) of knowledge in any element (structure) of the technological structure in the aircraft industry, the volume of the tetrahedron increases, that is, the general paradigm of knowledge of the technological structure increases.
The main advantage of the end-to-end technological structure in the aircraft industry is the reduction of the time period from the formation of the concept, the development and manufacture of new aircrafts and their systems, the development of products to their introduction into civil and military aviation.

**Air environment**

Figure 4 presents the Earth cutaway [12]. At present, the lower layers of the atmosphere are of practical importance for civil aviation: the troposphere and the lower part of the stratosphere (up to an altitude of 20 km) [6, 13]. When creating and operating the aircraft, the structure and parameters of the atmosphere are taken into account: pressure, density, temperature. In these layers, the pressure, density and temperature of the medium decrease when the altitude increases.

![Figure 4. Earth, cutaway.](image)

**Geoenvironment**

Geoenvironment is much more diverse and multifaceted in its properties and manifestations in comparison to the air environment.

Indicators of physical and mechanical properties of rocky and non-rocky soils (rocks), and there are more than 20 of them only by name [13], differ considerably among themselves.

When creating a promising technological mode of development (formation) of underground space on the basis of the advanced development of new approaches in building geotechnology and geotechnics, it seems necessary to fully take into account the experience and merits of the end-to-end technological structure created in the aircraft industry.

**Purposes of the concept**

*Strategic purposes:*

- Creation of a promising technological mode of development (formation) of underground space on the basis of the advanced development of new approaches in building geotechnology and geotechnics, providing a reduction in the period of time from the formation of design, development, production of new UV, fine-tuning of products and their systems to introduction into industrial and civil construction, units MES, MO.
- Creation of a new high-tech and knowledge-intensive engineering industry – geokhod engineering [14,15].
- Formation of a new segment of the mining engineering market and its capture.
Intermediate (tactical) purposes:

- Creation of experimental models of new types of products: geokhods, underground robots, mining structures and support [16].
- Creation and production of pilot batches of new types of products (geokhods of various standard sizes and functional purposes, resource-saving constructions of mine workings) [17–19].
- Creation of new geotechnologies for the formation and development of underground space, the development of underground transport infrastructure [20, 21].
- Creating a highly efficient and competitive mining technology of a new generation.
- Formation of the backbone infrastructure to speed up the process of creating and selling scientific and technical products in regions and Russia as a whole, bringing them to industrial use.
- Creation of production facilities for the manufacturing a new type of mining equipment, support of mine workings and lining of underground structures.
- Creating new jobs in depressed areas.

The way to achieve the goal

- Consolidation of efforts of the state, investors, scientific, design, production and educational organizations.
- Concentration of efforts on the chosen strategic and basic directions of activity.
- Creating competition in selected areas of activity.

The concept assumes the use of the program approach in solving the problem of formation of a new through technological structure.

Figure 5 conditionally shows the structure of a promising technological mode of development (formation) of underground space based on the advanced development of new approaches in building geotechnology and geotechnics.

![Figure 5](image)

**Figure 5.** The paradigm of the promising technological structure of development (formation) of underground space based on the advanced development of new approaches in building geotechnology and geotechnics.

The key elements (structures) of the technological mode of development (formation) of underground space are:
Geodynamics of underground vehicles. Fundamental science, studying the forces arising on the surface of a solid body moving in a solid environment.

The main task of geodynamics of an UV is to select a rational form of an UV for the purpose of obtaining specified technical characteristics, as well as determining geodynamic loads and heat fluxes acting on the surface of an UV, for strength calculations.

Geokhod engineering

1) The scientific discipline related to the design and construction of geokhods, UVs, moving in geoenvironment using the environment itself, underground robots [22, 23].

2) The industry engaged in the production of geokhods, UVs, moving in the geoenvironment using the environment itself, underground robots [24].

Geokhod engineering along with other industries should be the initiator of the new industrialization of the country, and also become one of the main consumers of products created in the framework of the implementation of the Concept of component engineering.

Center(s) of testing underground equipment. The emergence of new professions: test miner, test engineer of mining equipment, new methods and techniques.

1) Conducting full-scale ground and underground testing of UV moving in geoenvironment using the environment itself, underground robots and their systems.

2) Participation in the completion and modernization of UV moving in a geoenvironment using the environment itself, underground robots at all stages of their life cycle.

3) The introduction of tested UV, moving in the geoenvironment using the environment itself, underground robots and their systems in industrial and civil construction, units of the Ministry of Emergency Situations, MO.

Project and technological tools

1) Design of underground structures for various purposes, etc.

2) Navigation provision, etc.

3) Staff training.

4) Creating and improving the regulatory framework.

5) Ensuring the safety of flights and operation of work and operation of geotechnics.

In the aggregate, the elements (structures) of the prospective technological mode of development (formation) of underground space form a certain amount of knowledge – the Paradigm of knowledge of the technological mode. In figure 5, the paradigm is conditionally represented as the volume of a tetrahedron.

Main activity directions

– Development of scientific principles for designing geokhods and UVs moving in geoenvironment using the environment itself, underground multipurpose robots and their systems.

– Development of scientific bases of geodynamics of underground devices.

– Development of structures of geokhods, UVs, moving in the geoenvironment using the environment itself, underground robots, their elements and systems (geokhod engineering).

– Manufacturing of prototype models of geokhods, UVs, moving in geoenvironment using the environment itself, underground robots for various purposes.

– Testing experimental models of geokhods, UVs, moving in the geoenvironment using the environment itself, underground robots.

– Development on the basis of geokhods of mobile complexes for special purposes.

– Justification of the principles and the creation of new geotechnologies and the holding of underground workings.

– Development of technical solutions and methods for calculating support of mine workings and lining of underground structures for various purposes.
– Development of experimental models of support of mine workings and underground structures for various purposes.
– Manufacturing of experimental models of support.
– Testing experimental models of support.
– Creation, technical and scientifically-methodical equipment of the research center of underground tests.
– Creation of data acquisition and processing systems for the analysis of unique objects.
– Training of specialists for the design, manufacture, testing and operation of geokhods.
– Creation of scientific and technical products, software products.
– Design of underground structures, objects of underground transport infrastructure.
– Formation of a backbone scientific and project infrastructure, creation of manufactures for the production of a new type of mining equipment, support and lining of underground workings.

**Brief description of products (strategic direction)**

**Table 3. A brief description of products.**

| Main products                                           | 1. Underground vehicles moving in the geoenvironment using the environment itself, underground robots of various sizes and purposes.  
|                                                        | 2. Lining of underground facilities of various sizes.  
|                                                        | 3. Single-purpose mobile complexes. |
| Type of products                                       | 1. A new type of mining equipment (expert opinion).  
|                                                        | 2. A new type of support of mine workings and lining of underground facilities. |
| Product analogue                                        | Has no analogues |
| Application area                                       | 1. Mine workings of various location in space.  
|                                                        | 2. Construction of underground structures for various purposes:  
|                                                        | – city collectors;  
|                                                        | – magistral metro tunnels;  
|                                                        | – underground warehouses, storage facilities;  
|                                                        | – underground passages, garages;  
|                                                        | 3. Erection of fortification facilities.  
|                                                        | 4. Conducting rescue operations in the rubble. |
| Sales market                                            | 1. Enterprises of urban and municipal construction.  
|                                                        | 2. Transport construction enterprises.  
|                                                        | 3. Metro construction organizations, tunnel units.  
|                                                        | 4. Divisions of MO, MES, PMRU.  
|                                                        | 5. Underground coal mining enterprises. |

**Socio-economic results**
The implementation of the concept and the creation of a promising technological structure for the development (formation) of underground space based on the advanced development of new approaches in building geotechnology and geotechnics will allow:
– to reduce the costs of building underground facilities for various purposes (transport tunnels, subway, mines, factories, urban collection facilities, nuclear power facilities, warehouses, etc.);
– to increase the country's defense;
– to create mountain rescue equipment for conducting rescue operations in the rubble;
– to create a highly efficient and competitive mining technology and a new generation technology;
to export engineering equipment and technology;
– to create new jobs in depressed areas;
– to develop new Research and Development jobs;
– to create industrial enterprises for the production and marketing of new competitive products.

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