

Scientific and Technological Development, Technological Systems, Innovations and Their Importance for Space Sector of Ukraine

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The achievements of scientific and technological development of the space sector can be used only if adequate basic conditions for such development are provided, first of all, its proper and effective legal regulatory framework. The dialectical method enables to study processes of science and technology convergence of in the space sector. The scientific novelty is that the concept of technological systems is used as a theoretical basis for changing the emphasis from “scientific and technical” to “scientific and technological” development, which is historically justified. On the basis of the specified concept priority trends in the scientific and technological development of the space sector of Ukraine are listed. It is concluded that scientific and technological development in the space sector as a result of a new scientific and technological paradigm is a multifaceted phenomenon, proposed to be considered as 1) a complex multi-vector phenomenon and the highest socio-cultural value in the development of mankind; 2) direct causal relation with sustainable and inclusive development, general well-being and social progress in general; 3) an intensive factor influencing economic growth, competitiveness and national security of the state.

Keywords: space sector, scientific and technological development, globalization, technological revolution, paradigm, technological system, public administration, legal regulatory framework, innovations.

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Introduction

According to representatives of various scientific perspectives, the current stage of development of society and civilization is described as a “knowledge society” (David, 2003), “third wave society” (Collins et al., 2010), “the fourth technological revolution” (Prisecaru, 2016), “Industry 4.0” (Lasi et al., 2014). New phenomena and concepts emerge: technoscience (Law & Mol, 2001), cognitive science, NBIC technology (nano-bio-info-cogno) (Managing, 2006), CALS technology (Continuous Acquisition and Life cycle Support) (Rigby, 1996), High-Tech, High-Human, etc. Science and technology have a very fast pace of development, the time limits of the formation of technological systems are reduced, which indicates profound changes in society.

Despite the terminological differences of new concepts, it is all about the implementation of scientific and technological advances into socio-economic practice that enable to reduce the negative effects of existing socio-economic and environmental problems, avoid new ones, ensure a sustainable future for future generations. The above is confirmed by the “2030 Agenda for Sustainable Development” adopted by the UN General Assembly in 2015 (Take, 2021). There, for the first time, the role of science and technology is highly recognized as the most important factor in ensuring inclusive, sustainable development. This is due to the ability of States to mobilize existing opportunities, adapt to new globalization changes, to form new legal, managerial, organizational, financial approaches and tools of influence in the “permanent” technological revolution.

Therefore, a positive effect from the use of the scientific and technological achievements in the space sector can be only if adequate basic conditions for such development are provided, first of all, its proper and effective legal regulatory framework.

Analysis of Ukraine’s status in the global scientific and technological space is presented in international rankings and indices. They enable to assess objectively the scientific and technological potential, scientific, technological and innovative competitiveness of the state according to various social, economic and institutional indicators, including in the space sector. For example, the Global Innovation Index, published annually by the World Intellectual Property Organization, Cornell University and the Business School for the World INSEAD, assesses the elements of national economies in which innovation processes take place. For example, according to GII in 2020, Ukraine was ranked as the 45th out of 131 countries, receiving an index of 36.3 out of 100 possible for all indicators (in 2019, Ukraine was ranked as the 47th out of 129 countries with an index of 37.4 points; in 2018, the 43rd place among 126 countries with an index of 38.5 points) (Global Innovation, 2020). According to the Bloomberg Innovation Index, which uses indicators such as R&D intensity, manufacturing capability, technology company density, research concentration, value-added production, tertiary education and patent activity, in 2020, Ukraine was ranked as the 56th out of 60 with a total score of 53 (in 2019, the 53rd place with a total score of 48; in 2018, the 46th place with a total score of 42) (The Bloomberg, 2020). According to the 2020 Innovation Union Scoreboard Report, in 2019, Ukraine was classified as a country of “slow innovators” with a cumulative index of 32.9% (24.7% in 2018). According to the Global Competitiveness Index, which is calculated according to the methodology of the World Economic Forum and has, in particular, benchmarks such as higher education and training, level of technological development and innovation potential, Ukraine in 2019 was ranked as the 85th out of 141 participants (the 83rd place out of 140 participants in 2018) (Global Competitiveness, 2020).

These data indicate that the current model of public administration in Ukraine in the field of scientific and technological development in the space sector is inefficient. In addition to disabling the economic growth of the state, its competitiveness in the world market, it also poses real threats to Ukraine's national security. This has been repeatedly confirmed by national parliamentary hearings on problematic issues in the field of science (On the State, 2016), technology, innovation and space activities (On the Establishment, 2021).

In turn, science-intensive industries, such as rocketry, are major producers of new technologies and promoters of higher technological levels in the country. Moreover, the high-tech sector can help advance new technologies to less advanced sectors of the economy. It contributes to creating new jobs faster and at a lower cost, to economic development and growth (Scientific, 2001). For example, the famous analyst E. Mazareanu's report predicts that the global space economy will reach 1.1 trillion dollars by 2040, and the share of government spending in the global space economy will decrease from 25 to 17% (Mazareanu, 2019). To sum up, it should be emphasized that the sustainable scientific and technological development of space activities requires combining all available legal, financial, organizational mechanisms and using the opportunities of both public and private sectors.

In addition, the lack of comprehensive monographic studies considering scientific and technological development in the space sector as an object of the legal regulatory framework and a direct subject of scientific research; the presence of systemic problems of scientific and technological development in the space sector of Ukraine; the need to form a conceptually new model of the legal regulatory framework, taking into account global trends, global challenges and the commercialization of space activities justify the relevance and timeliness of our study.

Conceptual approaches to the doctrinal understanding of the convergence of science and technology in the space sector

Recently, the world community has focused on scientific and technological development in general and in space in particular. The development of science and technology is considered by the world community as key factors of sustainable development, and although in today's world there are anti-scientific trends, but science is seen as the highest value of human culture and civilization. Moreover, the socio-economic indicators of the state are determined by a set of its new technologies. In this regard, scientific and technological development in the space sector is considered by most highly developed countries from the perspective of one of the key priorities of public policy.

In the context of globalization and the ever-accelerating technological changes in the space sector, the issues of convergence of science and technology are increasingly relevant. They require rethinking and reassessment. The qualitative technological changes taking place in the world and the accelerated speed of such processes require not only individual States but also the world community to form new concepts of scientific and technological development in the space sector, based on the renewed role of States in these processes.

Nowadays, the technological role of science is particularly apparent due to active specific qualities of modern science – a new paradigm of science is being formed, we see fluctuations, evolution, complexity, diversity, interdisciplinarity and trans-disciplinarity. In addition, all these qualities, characteristics of modern science are manifested not only at the macroscopic level, for example, in chemistry, but also at the microscopic level, in particle physics, and on a cosmic scale, in modern cosmology. Finally, modern science is developing into a “knowledge

society.” The “knowledge society” is characterized by profound changes in society itself, for which new scientific knowledge and technology become the dominant of existence, the basis of society as an information society. Moreover, one of the specificities of modern science is the diversity of new technologies, contributing to the process of technologizing of society (Moiseeva & Andreeva, 2013).

There are several conceptual approaches to the convergence of science and technology from the perspective of philosophy of law, philosophy of science and technology, sociology, economy, such as civilization, technically stadial, paradigmatic and revolutionary. However, all the above theories have rather more in common than differ, generally in terminology and primarily due to being formed at different times – at different phases and stages of scientific and technological development, and, accordingly, each reflects the features of that time.

One of the cognitive tools that allow not only to understand the problems of modern society, but also to construct the future, as it is immanent in the present, is the paradigm of scientific and technological development, which allows to consider scientific and technological development in the space sector through the mechanism of historical paradigm shift (Shevchenko, 2012).

The concept of changing scientific paradigms was developed by the American historian of science Thomas Kuhn. He presents the development of science as an abrupt revolutionary process, the essence of which is expressed in the change of paradigms. Thomas Kuhn argues: “A paradigm is a universally recognizable scientific achievement that, for a time, provides model problems and solutions to a community of practitioners” (Ruzavin, 2012). According to Thomas Kuhn, these models give rise to specific traditions of one or another trend in the study. Paradigms have both cognitive and regulatory functions. They give scientists the basic principles of their cognitive activity and forms of implementation of these principles (Skutina, 2017).

According to Thomas Kuhn, science in its development undergoes a number of periods: pre-paradigmatic (when there are several scientific schools, several different theories about the same thing), the period of normal science (when all scientific schools adopt a common theory as a paradigm), the period of uncertainty and crisis (when scientific facts contradictory to paradigms occur), which ends in some cases with a scientific revolution (Kuhn, 1996). At the same time, the revolution in science is subject to the following scheme: first, there is an awareness of “anomalies,” i.e., the fact that the “paradigm” cannot cope with specific problems that arise in the development of “normal” science; then, to overcome the anomalies, numerous attempts are made to cosmetically “repair” the old paradigm, which, in case of failure, leads to a crisis situation where the anomalous fact can no longer be explained from the old paradigm, and solving the “puzzle problem” does not save the old theory. As a result, the old paradigm is replaced (Kondrakov, 2009).

In the development of science, there are turning points, crises, state of the art in knowledge, which radically change the former worldview (Perez, 2010). These turning points in the genesis of scientific knowledge have been called scientific revolutions (Golubintsev et al., 2008). In work “Scientific Revolution” (Dear & Shepin 2015), S. Shapin argues that O. Koyré in 1939 has made the concept of “scientific revolution” common, although in the 1930’s the French philosopher G. Bashlyar spoke of “mutations” in science (i.e., a high degree of discontinuity) (Khmelevskaya, 2017). The term “Scientific Revolution” became widespread in the 1950s, especially after the publications of “Scientific Revolution” (Hall, 1954) by A. Hall and of works by J. Bernal (one of the volumes of his “Historical Science” was called “Scientific and Industrial Revolutions” (Bernal, 2010)).

Next, some interpretations of the term “Scientific Revolution” come: Thomas Kuhn: “Scientific revolution is a noncumulative developmental episode in which an older paradigm is replaced in whole or in part by an incompatible new one” (Kuhn, 1996); I. Lakatos: “the scientific revolution is the fact of change of scientific (first of all, fundamental) theories, which are considered through the prism of its logical-methodological (rational) reconstruction, but not an event of real history and culture” (Lakatos, 2008). E. Agazzi: “Revolution is occurrence of a new form of knowledge” (Agazzi, 2017). P. Duem: “The independence of scientific revolutions is not obvious; it is a continuation of progressive trends in society” (Duhem, 1991; Khmelevskaya, 2017).

It should be noted that historically, the development of science differed from the development of technology. They were formed independently and separately; to some extent, even in isolation, scientific and technological revolutions did not coincide. In the middle of the 20th century, on the one hand, science began to interact closely with other spheres of life, and on the other, the number of new technologies increased, as well as the pace of their development and implementation based on the development of scientific knowledge. This process contributes to the gradual strengthening of the relationship between science and technology, is their synthesis. Accordingly, the process of scientific and technological convergence began, leading to a new phenomenon – the scientific and technological revolution (Kurkova, 2020).

To sum up, the technicalization of society and nature dates back to the agrarian revolution. However, such pre-industrial technologies were the result of trial and error, i.e., reflected practical experience, but not objective knowledge based on scientific results. In this way, the development of technology is directly related and is due primarily to the development of science.

With regard to the correlation between the terms “scientific and technical” and “scientific and technological” development, it should be noted that in different sources, the words “technology” and “technical” are used very ambiguously.

For example, the word “technology” comes from two Greek words, transliterated “techne” and “logos.” “Techne” means an art, skill, craft, method, or means by which a thing is acquired. “Logos” means a word, utterance, through which the inner thought, utterance, or expression is conveyed. Therefore, literally, technology means words or reasoning about how to achieve something (Technology, 2021). Therefore, in some cases it refers to state of the art in technology at some stage of social development, in others, to the method of production of any product, as well as to the industry that manufactures these products, and even to the product itself without a clear distinction between these three options (Avdulov & Kulkin 2010; Technology, 2021).

In turn, the word “technical” also comes from the Greek word “technikós,” that is, an art and crafts. It is equivalent to téchn (ē) + -ikos-ic (adj.) (Technic, 2021). Therefore, in many English dictionaries, the phrases “scientific and technical development” and “scientific and technological” have a similar interpretation (What, 2021) and are synonyms. However, in our opinion, scientific and technical development is an element of scientific and technological development, which has a broader interpretation. This is because, in essence, technology is what allows scientific knowledge to be applied in practice. This is a set of tools, methods, techniques, which is lined up in a logical chain, a protocol of actions in order to achieve the desired result.

To sum up, the development of science, technics and technology, their gradual synthesis led to a new phenomenon in the first half of the 20th century – a scientific and technological

revolution, which gradually, in the course of the change of technological systems has transformed first to the scientific and technological revolution, and overtime to a renewed phenomenon – scientific and technological convergence.

The preconditions for this phenomenon were the two World Wars, which affected the nature and pace of scientific and technological development in general and in the space sector in particular. These events led to the realization of the role of the scientific and technological potential of the country and the need for State regulation of its development, including the need to increase funding for science in space.

Despite the fact that scientific and technological development in the space sector has been and is more defensive in nature, it was aimed primarily at military needs. This process contributed to the overall acceleration of science. Later, the scientific results of the military industry began to be implemented for peaceful purposes. Therefore, rivalry in space forced States to intervene more actively in economic, scientific and technological development, which contributed to the rapid development of science and technology. As a result, the current situation in the world has forced States to accept the need for being active in the process of economic, social and, accordingly, scientific and technological development, as well as formed new priorities of public policy and public administration. Globalization and acceleration of scientific and technological development contributed to the fact that in the second half of the 20th century, issues of research and technological development in the space sector shifted from the national to the international level, began to form the foundations of international cooperation in this field.

Therefore, nowadays, we can observe a new scientific and technological paradigm: the convergence of science, technology and society as a cumulative result of previous scientific and technological revolutions, covering all sectors of social life and human life, including space.

The technological system of the country and its impact on the scientific and technological development of the space sector of Ukraine

It should be noted that an important pattern of global economic development is its irregularity, due to the periodic process of successive replacement of integrated complexes of technologically integrated industries – technological systems. In the context of scientific and technological progress, a new technological system is formed when the forms to combine means of labour, objects of labour and labour force in the process of production and services fundamentally change. At each stage of its development, society relies on a more perfect than the previous technological system (Sboyshakova, 2010).

The beginning of the theory of economic cycle is in the works of Nikolay Kondratiev. His theory's heart is the hypothesis that the scientific and technical revolution is built in a wave-like manner by changing technological systems with cycles lasting 40-60 years (N.D. Kondratiev, 2017: 6). In his work, Nikolay Kondratiev writes about “increasing” and “lowering” waves, focusing on the fact that at the beginning of each cycle before the rapid growth of science and technology, there are profound changes in the economic life of society. These changes are manifested in such phenomena as radical modernization of technology, the involvement of new countries in world economic communications, changes in gold mining, money circulation. He stresses that scientific and technological innovations play an important role. Each such cycle ends with a systemic crisis, which is the transition of productive forces to a higher quality stage of development (Zagidullina & Sobolev, 2014).

I. Schumpeter advocates the theory of long waves. In his writings, he argues that it is an innovation that contributes to long waves of business activity. According to him, innovations are “a sign of the technological revolution and its results.” He underlines that innovation in the economy creates a so-called “gale of creative destruction,” which shatters the balance of the existing economic system, leads to the elimination of outdated technologies and organizational structures, creates new strong industries. The result of this “gale” is an exceptional growth of the economy and the population’s well-being. I. Schumpeter presents innovation as a kind of catalyst for economic growth (Zagidullina & Sobolev, 2014; Schumpeter, 2008).

According to another group of scientists, the technological system should be understood as a set of technologies and industries of a single level, combined into a single integrated system of its industries, associated with flows of quality resources supported by the skilled labour force, general scientific and technical content (Zagidullina & Sobolev, 2014). Yu. Yakovets interprets the technological system as “several interdependent, successively replacing each other generations of technology, which evolutionarily implement the general technological principle” (Sboychakova, 2010; Yakovets, 2004). S. Hlaziev defines the technological system as a key factor, the core, the organizational, and economic regulatory mechanism. The core of the technological system is a set of basic technological processes that are actually used or are characteristic for a long time for sectors and branches of the economy, while material conditions for each new technological system are formed in the course of the previous one. The economy develops due to consistent changes in such systems (Sboychakova, 2010).

To sum up, the concept of technological systems is an effective tool for understanding the nature and patterns of scientific and technological development in the space sector. Therefore, in our opinion, the concept of technological systems makes sense to use as a theoretical basis for listing priority trends of scientific and technological development in the space sector of Ukraine.

The review of current perspectives enables to identify six technological systems (Kurkova, 2020).

The first technological system (1770-1830 – the first industrial revolution) is characterized by the development of the textile industry, the use of water energy, and as a result, factory production mechanization.

The second technological system (1830-1880) implies the development of the coal and metallurgical industries, railways, shipping based on steam engines.

The third technological system (1880-1930 – the second industrial revolution) implies the development of electrical and chemical industries (inorganic chemistry), heavy engineering (especially shipbuilding), the advent of radio and telecommunications, characterized by a concentration of banking and financial capital.

The fourth technological system (1930-1980 – the beginning of the scientific and technical revolution) implies the further development of energetics using oil (petroleum products), synthetic polymeric materials; chemical industry (organic chemistry); the beginning of the development of nuclear energy (both for military and peaceful purposes); widespread automotive, aircraft; developing electronics; computers and software products actively implemented; the beginning of rocketry and satellites; the beginning of mass production with the use of conveyor technologies; multinational and international companies actively investing capital.

The fifth technological system (1980-2020) is based on the achievements of computer science, microelectronics, genetic engineering, biotechnology, information and telecommunications

technologies, new types of energy, technopolis, technoparks, space exploration.

The sixth technological system (2010-2040) implies the development of nanotechnologies, photonics, optoelectronics, microsystem mechanics, molecular electronics, global information networks, artificial intelligence systems, information superhighways, Cals-Technologies (Continuous Acquisition and Life cycle Support), further development of the aerospace industry, the use of non-traditional energy sources.

Therefore, our study focuses only on the fourth, fifth, and sixth technological systems. Because in these systems, space technology has become the basic innovation and driving force of scientific and technological development.

It should be noted that today many scientists who study economic cycles recognize the importance of the formation of a new technological system. The outlines of this system arise in developed countries, such as the United States, Japan and the People's Republic of China; it is focused on the development and use of knowledge-intensive, i.e., "high technology." In the USA, the apportionment of this or that technological system is as follows: the fourth system makes 20%, the fifth is 60%, and about 5% belongs to the sixth system (Kablov, 2010). The United States was one of the first countries to enter the sixth technological system. The main prerequisites for this were a strong and stable political system, an effective mechanism for economic growth, scientific and technological progress (Zagidullina & Sobolev, 2014), as well as the promotion of national space activities.

With regard to Ukraine, economists argue (Fedorova, 2016; Bazhal, 2001; Dubyk & Osidach, 2014; Yerokhin, 2006) that today in Ukraine, there are mainly III and IV technological systems, and their total share is 95%. 58-60% of the output is accounted for by the third technological system, and 35-37% for the IV technological system (electricity and the use of oil and petroleum products as the main energy source; ferrous metallurgy; shipbuilding; light, woodworking, pulp and paper industries). The 5th technological system accounts for only 4-5%, and the 6th, the implementation of which determines the prospects for high-tech development of the country in the future – up to 0,1%.

The GDP growth due to the introduction of new technologies in Ukraine is estimated at only 0,7-1%, while in developed countries, this figure reaches 60% and even 90%. This situation is the result of errors in the transformation processes of the first years of independence (Dubyk & Osidach, 2014). According to the indicator of financing scientific and technical developments, the situation is as follows: today, almost 70% of funds are absorbed by the 4th and only 23% by the 5th technological systems. Innovation costs are distributed as follows: 60% for the 4th technological system and 30% for the 3rd (totally 90%), and the 5th is only 8,6%. With regard to investments, which, in fact, determine the future for the next 10-15 years, we have the following proportions: 75% go to the 3rd technological system, and only 20% and 4,5% go to the 4th and 5th technological systems respectively. In so far as technological capital investments (technical re-equipment and modernization) 83% falls on the 3rd technological system and only 10% – on the 4th (Yerokhin, 2006; Economy, 2003).

Therefore, scientific and technological development in the space sector of Ukraine does not meet the requirements of the time, and the priorities of public scientific and technological policy do not correspond to those prevalent in the world. This technological gap is growing every year, as a trend is that each subsequent technological system undergoes deeper changes, has a more comprehensive structure and properties, has a much shorter time frame.

Assessing the impact of scientific and technological revolutions, Klaus Schwab (Schwab, 2015) argues that new technologies are associated with uncertainty and many difficulties. This

implies the responsibility of all members of the world community, including governments, businesses, scientists, and the public, regarding close cooperation with each other, which is necessary to better understand the emerging trends. At the same time, he argues that governments are among those who will be most affected by this elusive and ephemeral force – the new scientific and technological revolution.

The coming revolution will affect both the States and public administration. The use of space technology will enable better management. More intensive and innovative use of web technologies can help public administrations modernize their structures and functions to improve overall performance. From strengthening e-government processes to greater transparency, accountability and involvement in the relationship between government and its citizens. Governments will have to change, as their central role in policymaking will diminish due to increasing competition, as well as redistribution and decentralization of power enabled by new technologies. Increasingly, governments will be seen as public service centres, assessed for their ability to deliver expanded services in the most efficient and individualized way. Ultimately, it is governments' ability to adapt that will play a key role in their survival. If they set transparency and efficiency levels for their structures enough for their competitiveness, they will stand the test of time (Schwab, 2015). However, Klaus Schwab doubts that States will not be able to adapt to new changes, and therefore will not be able to apply and implement new space technologies to benefit from them, and new changes will create new security problems.

Therefore, we can conclude that: 1) scientific and technological convergence necessitates the search for ways to adapt to the transformational conditions of modern "knowledge society" in the face of global challenges and the formation of a conceptually new model of scientific and technological development in the space sector; 2) the development of science and technology in space and their convergence determines and provides an opportunity for innovative modernization of approaches to structural organization, functions, mechanisms and methods of public administration for the benefit of people.

Conclusions

The current stage of human development is characterized by global scientific and technological transformations, while the life of society and the state is largely determined by state of the art in science and technology in space, which today affects absolutely all spheres of social reality. Various aspects of human life are subject to space technologization: from the Human Genome Project to e-governance.

The globalization and growing acceleration of technological changes make the issues of convergence of science and technology especially relevant, which requires rethinking and reassessment. This is because the qualitative technological changes taking place in the world and the accelerated speed of such processes require not only individual States but also the world community to form new concepts of scientific and technological development in the space sector, based on the renewed role of States in these processes.

Scientific and technological development in the space sector as a result of a new scientific and technological paradigm is a multifaceted phenomenon, which should be considered as 1) a complex multi-vector phenomenon and the highest socio-cultural value in the development of mankind. Moreover, the multi-vector nature of scientific and technological development is: legal, ethical and moral aspects; positive and negative consequences of technologization of science; responsibilities of all members of the world community (public, scientific, educational,

commercial sectors and civil society, individual representatives of each of them); 2) direct causal link with sustainable and inclusive development, general well-being and social progress in general; 3) an intensive factor influencing: economic growth and competitiveness; national security of the state, and, as a consequence, one of the key areas of public policy.

Therefore, the concept of technological systems is an effective tool for learning the essence and patterns of scientific and technological development in the space sector. The study proposes to use the concept of technological systems as a theoretical basis and reference point for listing priority trends of scientific and technological development in the space sector of Ukraine.

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