Space technologies in achieving the aims of sustainable development

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Abstract. Space technologies are currently being actively developed and applied in all spheres of economic activity, are recognized as one of the key innovative tools for achieving the global programs goals, allow forming the most effective solutions to a wide range of tasks. There is a significant annual increase in private investment in the global space ecosystem development, which is associated with the improvement of small satellites’ technologies, an increase in international private projects, global competition. It is proved that the development of space technologies has led to technologies intensification for Earth remote sensing, stimulating the industries’ growth, the telecommunications sector, creating conditions for retaining and attracting highly qualified labor, increasing competencies in the highly intelligent methods and products development, ensuring the technological security of countries and improving society’s life quality. The most significant effects from the space technologies use to achieve the ten SDG are highlighted. The limitations of space technologies application are shown due to poor awareness, lack of experience, skills in the field of ML and AI, partial data closure, insufficient financial resources, infrastructure for launching spacecraft and conducting astronomical research.

1. Introduction
For the last several years a swift space technologies and geospatial services penetration into the economic, ecological, social, political and legal spheres in the interests of the sustainable development, the development of the society and worldwide economical growth is observed [1]. They are acknowledged to be the key innovative instruments for achieving the aims of a range of global development programmes, for instance, Sendai Framework for Disaster Risk Reduction 2015–2030 and Paris Agreement. The information obtained with the help of space technologies and their applications allows finding more effective solutions to the key problems, which the world community faces, including the spheres of public health, education, food security, agriculture, the climate change, management of energy and natural resources, lessening of disasters’ risk and sustainability strengthening [2].

The importance of implementing the results of the space science and space technologies for solving the problems in the sphere of the sustainable development contributed to the formation and implementation of the programme “Space 2030”, aimed at the increase of the space role in the long-term society development, and containing the descriptions of the space data, space infrastructure, services and applications influence on the degree of the main framework programmes accomplishment [3]. The programme “Space 2030” includes four main areas: “Space Economy”, presenting the ways of getting the economical benefits due to the usage of space technologies; “Space Society” in the...
frames of which the ways of getting social benefits due to the space activity are formed; “Space Accessibility” implies the organization of the access to the space technologies, infrastructure and the data of all the society members; “Space Diplomacy” being aimed at the strengthening of the international cooperation and adjustment of the partnership relations between the countries of the world [4].

The objective of the research is to conduct an empirical study of the tendencies in the development of space ecosystem, low-orbit satellite communication systems in the Russian Federation and other countries, to single out the effects of using the space technologies for gaining the sustainable development goals.

2. Methods and the results of the research

The world space ecosystem is developing very rapidly. In general, the lowering of costs on developing and manufacturing of the ground and satellite equipment, the decrease in the costs on launching satellites, the improvement of the infrastructure of the data storage and cloud calculations technologies contribute to the intensive development of the world space ecosystem, which is estimated at 378 bn $ in 2020. Along with this, the start-ups activization, involvement of the private sector investments, making state-private partnerships in the sphere of space technologies are the most important factors, ensuring the formation of the modern space ecosystem. In 2020 the amount of private investments into the space sphere was 16.5 bn $, having increased by 32.5 % in spite of the world financial crisis, caused by the spread of the new coronavirus infection.

The active involvement of the private companies into the sphere, traditionally taken up by the military services of different countries, was promoted by the appearance of the small satellites technology; the small satellites are mainly used to watch the Earth and provide the access to the information-telecommunication technologies from any spot of the world. The necessity of the small satellites’ technical characteristics improvement in its turn led to the intensification of the development of microelectronic industry and the Earth distant probing technologies, as well as to the increase in the efficiency of different structural subsystems’ functioning, for example, power sources, propulsion systems and controlling systems, being equipped with the technologies of the artificial intellect.

Nowadays the largest international private project in the sphere of space technologies is the project Starlink of the American company SpaceX. Within the frames of this programme it is presupposed to launch more than 11,000 satellites to the low circumterrestrial orbits. These satellites, using the mobile satellite communication technologies through the terminal gateway, are able to provide the users with a high speed wideband access to the Internet due to the whole planet surface coverage. It is assumed that the speed of the data transmission will reach 1 Gb/sec, this is comparable to the access characteristics in the frames of the standard of 5G cellular communications, and the total costs on launching and connecting the satellites to the integrated net will be about 10 bn $. According to the data (April 2021), the satellite grouping SpaceX was more than 1.3 thousand items. Till the end of the current year the company intends to expand the satellite communication in 25 countries, as well as to provide moving objects, such as ground transport, sea vessels and aircrafts, with the access to the satellite Internet.

The main competitors of the project Starlink in the world are the projects of the American company Iridium Communications, the Chinese company GalaxySpace and the Canadian company Telesat. In particular, the grouping of the satellites Iridium Communications at present is about 150 items, besides, the launch of the new generation satellites is implemented with the usage of SpaceX resources. In January 2020 within the frames of the Chinese company GalaxySpace project the first wideband internet-satellite was launched on the low circumterrestrial orbit with the data transmission speed 24 Gb/sec (the access is provided only to the Chinese users). This programme presupposes the total launch of about 13,000 low-orbit satellites. According to the Canadian company Telesat data, 298 satellites are planned to be launched by 2023, and the full coverage is likely to be achieved in the second half of 2024.
In Russia the development of low-orbit systems of the satellite communications for providing services to access the information-telecommunication Internet at present is realized in the frames of the global satellite communications system project “Sfera”. The project provides the consolidation of the satellite navigation system GLONASS, the system of the Earth distant probing, satellite communications and broadcasting, the global system of the things internet “Maraphon IoT/M2M” and the middle orbital system of the wideband access to the Internet “Skif”. According to the preliminary assessment the costs on the creation and deployment of the satellite communications systems from the spacecrafts on the high-elliptical orbits of the type “Molniya” and “Express-RV” will make up about 77 bn roubles. In particular, for manufacturing 5 aircrafts of the series “Express”, used in the systems of the satellite communications, 42.1 bn roubles will be granted in the frames of the federal project “Digital infrastructure” of the national programme “Digital economy”. Totally, for guaranteeing the operation of the merged system the satellite grouping, consisting of 600 spacecrafts, is supposed to be created by 2030.

The assistance of the private participants to the space activities and the growth of the investments into the development of the space infrastructure promote getting larger economical and social effects than the growth of the gross domestic product and the employment. In particular, the development of the space sphere presupposes the stimulation of the growth of industry branches, which are involved into the chain of manufacturing products for the space industry (for instance, chemical and electronic industries, metallurgy and information-telecommunication sector). This, in its turn, allows creating conditions for keeping and involving highly-qualified manpower, stimulating the increase in the competencies in the area of development of native highly-intellectual technologies and products, and guaranteeing the technological safety of the country as well as improving the society’s life quality [3].

Besides the positive influence on the industrial economy sector state, the development of the space ecosystem allows gaining the UNO Sustainable Development Goals (hereinafter referred to as SDG). The joint research, carried out by the United Nations Office for Outer Space Affairs (UNOOSA) and the EU Agency for the Space Programme (GSA), showed that out of 169 tasks being in the basis of SDG, about 40% of their completion to an extant degree depends on the access to the space science and technologies (Table 1) [5]. Space technologies will influence all the SDG tempo advancement positively.

According to [10] the use of space technologies allows increasing the quality of forecasting the solar activity by 30%, as well as obtaining more than 50% unique information, connected with the climate change. In its turn, according to the state corporation “Roscosmos”, the deployment of the global satellite communications system “Sfera” must allow providing the decrease in the costs on the construction by 15% due to the distant assessment of the territories and approaches, guaranteeing industrial safety and implementing twenty-four-hour supervision of the construction. Tracing the animals, control of the logistic operations and soil state, as well as automation of the managerial tasks allow reducing the expenditure in the agriculture by 30 %. Tracking the location and the technical state of the vessels, the organization of data exchange among the unmanned transport and creation of the automatically renewed timely 3D-map of the territory will contribute to 15% of economy in the loads logistics.

The development of space technologies also allows improving the life quality of the society, especially in the developing countries, by connecting them to the satellite net of the data transmission. In particular, the expansion of the satellite communications coverage has to allow providing the communication services to 49% of the world population, which at present is out of the zone of the communication nets’ ground infrastructure [10].

The population’s use of the satellite communications to the Internet access has the following advantages:
- An extensive usage and high quality of the data transmission. The satellite communication, in contrast to the ground nets, provides a stable quality of the service without depending on the geographical position and the distance from the ground infrastructure to the location of the end user. Despite the fact, that satellite connection still cannot provide the speed, corresponding to the most
modern connection standards (5G), that is necessary for providing a definite kind of the services (for example, online games), it can meet the requirements of most standard applications and programmes, which are used by the consumers. Due to the relatively close position to the Earth surface (the circumterrestrial orbit is about 1,000 km) the delay of the signal transmission between the user’s equipment and space apparatus decreased (from 250 ms to 15-20 ms), this allowed achieving the data transmission speed comparable to the speed of the fibre optic communication lines.

- A quick access to the services. To use the services of the satellite communications the users only have to install the end equipment – the connection to the net infrastructure is not done.
- A high profitability. The cost of the connection to the satellite communications does not depend on the territory characteristics and the population density. This leads to the formation of the unified price for all the users. In the opinion of the experts, the satellite technologies are the most profitable solution for providing the wideband communication in the areas with the low population density (usually less than 150 people per km²).
- The reliability and safety of using the services. The satellites are characterized by the limited downtime and minimal irregularity during its all span (about 15 years for the satellites on the geostationary orbit).

**Table 1. The application of space technologies for achieving the aims of the sustainable development.**

| The sustainable development goals | The effect of space technologies application |
|----------------------------------|---------------------------------------------|
| “Zero hunger”                    | Monitoring and struggling against the desertification and deforestation; guaranteeing the sustainable land use; the growth of crop capacity; optimization of the irrigation processes, the fertilizers’ and pesticides’ use; mapping of poor areas. |
| “No poverty”                     | Studying the processes of medicine distribution; monitoring the epidemiological situation and reaction to the diseases outbreaks; monitoring the air quality; assessment of being ready for the natural disasters and increasing the reaction to their beginning; early warning about the extreme weather conditions. |
| “Good health and well-being”     | The growth of the youth involvement into the space sphere by popularizing space exploration and the increase in the technologies implementation; providing the access to the information (including educational) from any spot on the globe using the Internet; creating the conditions to involve women into the space sphere. |
| “Quality education”,              | Forecasting the weather conditions, and floods; the quality and degree control of water resources pollution; monitoring the area of shallow waters; mapping and monitoring of the ocean and coastal territories, tracking and navigation of the fishing boats, monitoring of the illegal fisheries; tracking the ice and snow cover movement, probing the dimensions of the polar ice. |
| “Gender equality”                | Monitoring the speed, quality and safety of the street traffic; the assessment of quality and degree of the air pollution in the municipal districts; the control over the waste management. |
| “Clean water and sanitation”,     | Monitoring and struggling against the desertification and deforestation; struggling against illegal wild animals’ trade; the evaluation of the natural habitats’ degradation; quantitative assessment and modeling of biodiversity; optimization of natural resources; monitoring the reduction of greenhouse gases emission. |
| “Life below water”               |                                                                             |
| “Sustainable cities and communities” |                                                                             |
| “Climate action”,                 |                                                                             |
| “Life on land”                   |                                                                             |
Besides, providing the services of the satellite communication does not technically depend on the traditional telecommunication providers [11].

However, despite the decrease in the cost on the development of some space technologies and the applications for them, and the increase in the access to the data obtained with them, at present their usage is restricted by a range of factors in definite spheres and countries of the world. In particular, the growth of the space technologies popularization is interfered with the insufficient awareness of their usage advantages and probable effects of the economy growth and sustainable development, as well as the absence of the experience in using the satellite data [12]. The exponential growth of the data volume, collected with the satellites, requires the researchers’ availability of significant calculating capacities and highly-qualified staff, having the corresponding skills in the area of machine learning and artificial intelligence. The obstacles for a wider use of the satellite technologies are as follows: a partial closedness of the data, the absence of the unified standards of collecting and processing data, insufficient observation frequency, and also a low quality of the generated data. The development of the space ecosystem of the world developing countries is also restricted by the absence of the domestic and international financial resources, and the lack of the availability of the infrastructure for launching spacecrafts and carrying out astronomic researches [13].

The authors of the research [14] highlight the special importance of carrying out the space researches and the development of space technologies within the scope of the planetary sustainability as a part of the general sustainable development of our planet and in its space environment. This presupposes the development of the global policy and space law, following the rules of the peaceful exploration and use of the space resources, including circumterrestrial asteroids, lowering and controlling the orbital waste, and microorganisms’ pollution. It is also mentioned that the space environment can be 18 SDG itself for preventing its pollution and irreversible damage due to the uncontrollable usage of the space resources.

3. Conclusions
The lowering of costs on developing and manufacturing of the ground and satellite equipment, the decrease in the costs on launching satellites, the improvement of the infrastructure of the data storage and cloud calculations technologies, the appearance of the technology of using small satellites for distant Earth probing, the necessity of covering the whole planet’s surface with the satellite Internet greatly contribute to the intensive development of the world space ecosystem and to the involvement of the private sector investments. The implementation of the projects Starlink of the American company SpaceX, the American company Iridium Communications, the Chinese company Galaxy Space, the Canadian company Telesat, the Russian project of the global satellite communication system “Sfera” presupposes launching about 25,000 low-orbit satellites.

The development of the space sphere leads to the stimulation of the industry branches’ growth, which are involved into manufacturing products for the space industry, as well as to the involvement of highly qualified manpower, and induces to increase the competencies for the development of highly intellectual technologies and products.

The determined effects of implementation of the space technologies and their applications for SDG “Zero hunger”, “No poverty”, “Good health and well-being”, “Quality education”, “Gender equality”, “Clean water and sanitation”, “Life below water”, “Sustainable cities and communities”, “Climate action”, “Life on land” are called upon the decrease in the limitations for the use of the space technologies owing to the insufficient awareness of the advantages and probable effects of the economy growth and sustainable development.

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