PROSPECTS FOR SPACE-BASED EARTH OBSERVATION SYSTEMS IN UKRAINE

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Abstract. This article is devoted to defining the prospects of Ukraine in developing and launching Earth observation space systems, the problems that slow down this process and ways to solve them. The relevance of the research lies in the necessity of creating own remote sensing satellites and their constellations for civil and defence sectors. The purpose of the article is to develop effective directions for solving the problems hindering the creation of Earth observation space systems in Ukraine. To achieve the stated objectives, the concepts "Earth observation" and "Remote sensing" were, defined the field of application of Earth observation systems and their significance for our state were established. Based on an analysis of the experience of the USA, China and India and, the current, status of the Ukrainian space industry, the problems that hinder the establishment and development of Ukraine's own satellite constellation of space observation systems were determined. Proposals to resolve these problems were defined, and developed. The study used general scientific methods, which include the method of analysis, synthesis, comparison, induction and deduction. The study showed that Ukraine has significant prospects for the development of space surveillance systems, however, a number of problems in the space industry prevent the process from being, launched. In particular, the National Target Scientific and Technical Space Program for 2021–2025 remains unapproved, there are no investors ready to fund Ukrainian developments, national spacecraft are technologically backward and nondurable, and the loss-making State companies do not allow to work on complex projects. There is also a lack of qualified personnel to implement the tasks envisaged by the Program. These issues can be

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resolved by initiating the consideration and approval of the Program by the Verkhovna Rada of Ukraine, co-operation with other countries, introduction of new technologies, involvement of private companies, ensuring decent pay. Practical value of the study consists in the possibility of application of its results in the space field.

Keywords: Space surveillance systems, Remote sensing of Earth, Satellite constellation, Optoelectronic modules, Space program.

1. Introduction

The question of observing Earth from space is gaining more and more popularity. The information that can be, obtained with the help of space systems is, used in the most diverse spheres of life: Ecology, Hydrometeorology, Oceanography, land management, etc.

Thanks to the data obtained from satellites, it is possible to update and receive accurate information about seismicity in certain areas, to monitor the scale of, emergency, situations and environmental pollution. It is also possible to track climate change patterns occurring on the planet. The application of satellite information in the military sector is no less important.

Ukraine has a significant space potential and everything necessary for the creation of space technology. However, today it is, forced to purchase foreign products. Our State needs its own space resources, so the question of the prospects for creating space systems for observing the Earth is very relevant.

Space systems for observing Earth, which are, used in the civil and military sectors, are, considered in the works of many modern scientists. Among them are O.V. Tomchenko [1], V. Saakova [8], O. Indyukhova [8], L. Steka [9] and other researchers.

To date, the question of the prospects for creating space-based Earth observation systems in Ukraine, which has all the necessary resources for this, remains unexplored. Taking into account the above, the purpose of the article is to develop effective solutions to the problems that hinder the creation of space Earth observation systems in Ukraine.

2. Earth observation is one of the important components of national security

Every modern economic system needs state support and state regulation. Undoubtedly, the market has a significant influence on the determination of

key points for public financing and allocation of funds, this cannot happen in conjunction with market laws. Thus, the system of state support and state regulation of space activities consists in the implementation by the state of certain activities aimed at achieving specific goals to ensure the stable development of the domestic space industry.

Earth observation is the collection of data about the Earth's physical, chemical, and biological systems. It is, carried out using remote sensing technologies. In turn, remote sensing of the Earth (RSE) is the observation of its surface by ground, aviation and space means with special filming equipment [1].

Earth remote sensing spacecraft are used to obtain information about dangerous, hard-to-reach objects and objects that move quickly, and also allow observation over large areas. For example, remote sensing is used to monitor deforestation (for example, in the Amazon basin), the state of glaciers in the Arctic and Antarctic, ocean depth measurements, and other purposes.

Space technologies guarantee a technological, scientific, military, political and economic advantage, make it possible to carry out remote sensing of the Earth, allow to prevent emergency situations, increase the efficiency of exploration and extraction of natural resources, the introduction of innovative practices in agriculture, provide communication and navigation, environmental protection and climate change monitoring.

Even the short-term feeding of this industry affects the economy and security of the country in general. For the development of new missiles and equipment materials, significant volumes of metals, high-precision measuring equipment and specialists are always required. In other words, mechanical engineering and metallurgy are actually suffering, and such an economic parameter as unemployment, on the contrary, is increasing in percentage. Highly qualified engineers, signalmen, specialists in telecommunications and radio-electronic systems are forced to look for jobs outside of their specialty.

In recent years, one of the most important global factors is space, the success of which is actually an indicator of gaining world leadership and subsequent strategic dominance in the 21st century. An important segment of the high-tech market is the space market. The space industry of each country is one of the most competitive, since it includes a significant number of high-tech enterprises representing the country in the global high-tech

market. The space technology market is developing rapidly, participation in the supply of products and services is an important component of the scientific and technical development of any country. The implementation of programs of fundamental space research will allow to satisfy the needs of scientific schools of the state with information in the interests of forecasting and operational monitoring of "space weather", to continue the study of the planets and their satellites, to expand knowledge about the Earth and the processes taking place on it.

Remote sensing, carried out with the help of space systems, has replaced expensive and slow methods of collecting information from the surface of the Earth. It guarantees human non-interference in natural processes in the territories under observation.

Space observation vehicles provide the opportunity to collect and transmit data in various ranges of the electromagnetic spectrum. Combined with larger-scale aerial and ground-based measurements and analysis, they provide the necessary amount of data to monitor current phenomena and trends.

Remote sensing is important in the field of geosciences and agriculture. Earth remote sensing spacecraft are widely used to resolve military tasks during armed conflicts in any part of the planet.

3. Financial and technological capabilities of the developed countries of the world to improve remote sensing of the Earth

The space industry of Ukraine should concentrate modern scientific and technical developments and be a driving force for the growth of the high-tech sector of the economy. Therefore, legal support for the purpose of effective state regulation of space activities is an urgent and important issue for ensuring the sustainable development of this industry, which is able to provide the basis for technological leadership and long-term strategic advantages in globalization conditions.

As the scopes of application of data obtained through remote sensing of the Earth grow, the active development of space vehicles and space technologies of remote sensing is taking place. Understanding their importance, the technologically developed countries of the world pay considerable attention to this issue, which is, confirmed by the annual increase in the number of Earth observation satellites.

As of September 1, 2021, there was a, total, of 4,550 satellites in Earth's orbit. Of these, Earth remote sensing satellites make up 22.1%, i.e. 1005 units [2]. According to the data of the United States Geological Survey (USGS), the United States government research organization, as of June 2, 2022, the largest number of Earth remote sensing satellites belongs to the United States, China, India, Russia, Finland, Argentina, and France (Figure 1).

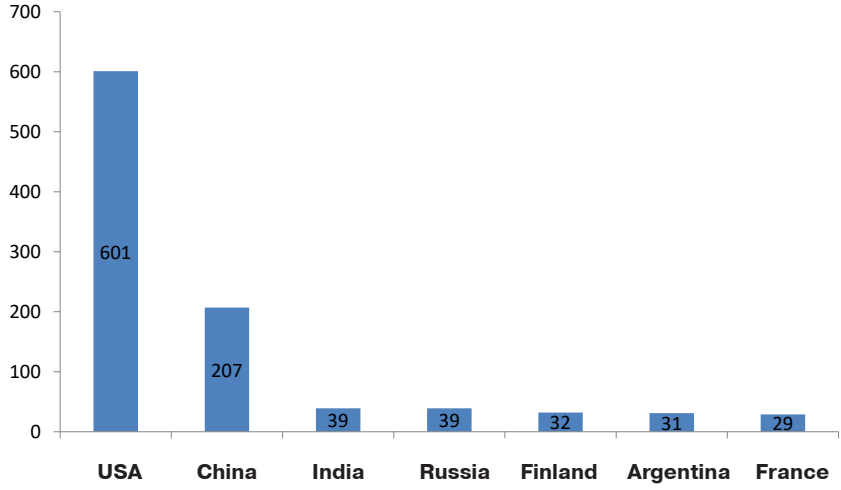

Figure 1. Number of remote sensing satellites by country in 2022

Source: systematized by the author [3]

The Dewesoft research team analyzed data collected by UCS, ESRI and the Space Foundation satellite database to compile a list of the largest owners of remote sensing satellites.

As of September 1, 2021, SpaceX is the leader in the number of satellites launched into orbit. It is followed by OneWeb Satellites, Planet Labs Inc., Ministry of National Defense of China, Spire Global Inc., Ministry of Defense of the Russian Federation, Spire Global Inc., Iridium Communications Inc., National Reconnaissance Office (NRO) [2].

Based on the above data, it can be, said that the United States pays the most attention to the development of space systems for observing Earth,

which has six hundred and one (601) successfully operating satellites. In particular, this country encourages the development and use of new space vehicles on a commercial, basis. Therefore, most satellites are, created by private companies.

In particular the, remote sensing satellites of one of the largest Landsat programs have, been assembled and launched, by Orbital Sciences Corporation since 1972. On September 27, 2021, the Landsat 9 device with the most advanced optical and infrared equipment was, launched into orbit, which allows obtaining information about global climate changes and monitoring the situation with the planet's natural resources [4].

Not far behind the USA is China, which is constantly working on the creation and launch of new space satellites. China has two hundred and seven (207) units of such equipment on their account. The latest development in this direction has been optical remote sensing satellites, designed for surveying territories, urban planning, confirmation of land rights, road network design, yield assessment, prevention and mitigation of natural disasters, etc. They are probably also used for military intelligence. The launch of RSE satellites took place on June 23, 2022 [5].

India is an active developer of remote sensing satellites.

India is not, considered to, be a space power, to the same degree as the USA or China, but it has its own ambitions, which it is gradually realizing.

On February 14, 2022, it launched its newest Earth-sensing radar satellite, EOS-4, too acquire high-quality images of the Earth's surface in areas such as agriculture, forestry, hydrology, flood mapping, etc. [6].

Other countries are also engaged in the development of space surveillance systems. Among them, we can name Ukraine, which, despite the war, on January 14, 2022, launched its first space probe of the Earth, Sich-2-30.

Ukraine has a significant scientific and industrial base, so it has the opportunity to independently, create space technology. Ukrainian enterprises can produce not only rocket launchers, but also satellites for remote sensing of Earth, which are of strategic importance in the conditions of a war with Russia.

However, despite the great potential of the space industry, during the years of independence, 7 spacecraft were developed and launched, none of which are operational anymore (1995 – Sich-1; 1999 – Okean-O; 2004 – Sich-1M Micron; 2007 – EGYPTSAT-1; 2011 – Jan-2; 2014 – POLYETAN-1; 2017 – POLYETAN-2).

Leading space technologies are a guarantor of technological, military, scientific, political and economic advantages, as well as a factor in communication and navigation, environmental protection and climate change monitoring. It is space technologies that undoubtedly ensure and increase the effectiveness of state intelligence. Therefore, investment in the development of the domestic space sector is an extremely important and urgent issue, since this high-tech segment is able to provide prerequisites for long-term strategic growth and technological leadership, especially in the post-war period.

Taking into account the global trends in the development of the rocket and space sphere and the limited possibilities of the state budget of Ukraine, it is advisable to take the following measures to intensify the international activity of the industry and increase its competitiveness. The basis of Ukraine's state policy in the field of rocket and space activities is to accept the expansion of international cooperation with the world's leading space and rocket-building companies and the implementation of high-priority economically feasible national projects within the limits of possible financial support.

To ensure the modernization of the existing and the preparation and creation of a new technological, experimental industrial and production base of the industry. To ensure the timely receipt of funds provided for by the state budget, the prevention of a decrease in real funding, as well as the continuity of funding, excluding the practice of receiving funds at the end of the year. Provide state support for the implementation of international rocket and space projects by providing state guarantees for the necessary investments. Provide for an increase in state orders to higher specialized educational institutions in the fields of rocket and space.

4. The unity of regulatory, financial, scientific and technological components to ensure effective use of the potential of the space activity of Ukraine

The situation can be, changed by the approval of the Concept of the National Targeted Scientific and Technical Space Program of Ukraine for 2021–2025. The relevant Order was, adopted by the Cabinet of Ministers of Ukraine on January 13, 2021 [7].

The implementation of this program will help ensure the effective use of the potential of the space industry to solve the current problems of society –

social, economic, environmental, informational, educational and scientific. The program is, also aimed at ensuring national security and defence of the country.

The program envisages the gradual creation of a national surveillance system based on orbital means and information technologies of domestic and foreign production. In accordance with the provisions of the Program, it will make it possible to control natural and manmade emergency, situations, and thanks to co-operation with the International GEOSS system, to solve problems of a regional and global scale.

In order to meet the needs of the State, it is, planned to create and develop its own space surveillance satellite group. According to the Program, it will be, based on Ukrainian platforms and scanners with medium and high resolution [7].

As part of the Program, eight satellites intended for Earth observation should be, launched into space. All of them must perform their tasks in orbit by 2025. In this way, it is, planned to create its own space group, which is necessary for the performance of many civil and defence tasks. Both before the war and during it, Ukraine buys data from space. Today, they are provided by, more than twenty (20) satellites, most of which are American and European [8].

Millions of dollars are, spent on this. Having your own satellite group or at least your own satellite makes it possible to receive information for the civil and military sectors at any time and without any restrictions.

The fact is that the sellers of pictures are not always able to provide information at the right time. In addition, such images are, provided to Ukraine with some restrictions. This fact, was established back in, 2015 by American journalists.

The Wall Street Journal published an article about the fact that the quality of images provided to our state are being, deliberately degraded.

Data is, sent with a delay, and the territory of the Russian Federation is, blacked out. According to the authors of the publication, this was, done deliberately by the administration of President Barack Obama in order not to provoke Russia into an armed conflict [9].

Today, no such facts have been, discovered, but there are still some restrictions on receiving satellite images.

All this once again confirms the need to create one's own group of satellites. It can be, said that it began with the launch of the "Sich-2-30"

Earth remote sensing spacecraft. Its technical characteristics are significantly inferior to foreign analogues, because its spatial resolution is only 7.8 m per one (1) pixel, and the band coverage is 46.6 km. This device is not capable of seeing small details, so it is, considered "overview".

Therefore, Sich-2-30 is not of great value to the military, although the satellite will benefit civil structures, scientists and the State Emergency Service.

Other remote sensing satellites, which are, planned, to, be launched before 2025, will have more powerful characteristics than Sich-2-30. In particular, they will have high (up to 1-2 m) and higher resolution (up to 0.5 m), which is very important for the military sector.

It should be noted that today Ukraine has all the necessary resources to create satellites of RSE with a spatial resolution of up to 2 m. However, reconnaissance devices, the spatial resolution of which exceeds this indicator, require foreign technologies. In particular, we are talking about technologies for the production of optical-electronic modules.

The complexity of the production of such powerful equipment determines its high cost. Thus, according to experts' estimates, a satellite with a spatial capacity of 0.5 m costs from seventy (70) to one hundred (100) million dollars.

It is, planned that most of the satellite will be, manufactured by Ukrainian enterprises. An optical-electronic module, solar and rechargeable batteries will be, purchased.

At the same time, in the coming years, it is, planned to create our own optical-electronic systems with ultra-high spatial resolution. For this, the Program for 2021–2025 plans to allocate UAH 2.4 billion [10].

Ukraine does not have its own optical-electronic scanner, on the, basis of which an optical-electronic system is being developed. Therefore, the plan is to allocate another three hundred and fourty (340) million hryvnias for its development.

If these plans are, implemented, the Ukrainian military will receive powerful reconnaissance devices and will be able to track small objects, such as groups of people, military equipment, etc.

The Ukrainian military needs not only optical, but also radar devices. The images obtained from such satellites are, created based on the information of a radio signal reflected from the earth's surface. The advantage of such a spacecraft is the ability to take pictures at any time and in any weather.

There is a steady trend to increase the importance of the benefits of services provided by space systems. The most important reasons for the growth of interest in the services and goods of the space market can be considered:

– informatization of all aspects of life in modern society;
– globalization of the world economy;
– military escalation;
– growth of environmental problems;
– development of international contracts, transport, tourism, etc.

Unfortunately, Ukraine does not have the opportunity to create such a satellite, so its development and launch are not in the plans for the coming years.

Several Ukrainian enterprises are working on the development of remote sensing satellites. The most active among them is the Design Bureau "Southern" named after M. K. Yangel. The State-owned enterprise has developed projects for an optical-electronic surveillance satellite with high and ultra-high resolution. OKB "Storm" is working on projects of space vehicles that will be, used to observe Earth.

It is, planned that they will be, released in 2023, if an investor is, found. After all, in order to start the device, one hundred and twenty (120) thousand dollars is, needed. It should be noted that thanks to the commercialization of the space industry, private companies, can also, work on the creation of surveillance satellites [11].

Considering all of these reasons, we can conclud that the creation of its own space-based Earth observation systems in Ukraine has significant prospects.

However, there are. a number of, problems that, may, prevent the implementation of the plan for the coming years.

1. The national targeted scientific and technical space program for 2021–2025 remains a project. The document has not, yet been submitted for consideration by the Verkhovna Rada of Ukraine. Currently, it is not, known whether this law will be adopted at all.

2. Lack of investors. According to the Program, funding of the space industry for 2021–2025 will amount to UAH 40.78 Billion. UAH 15.76 Billion will be, allocated from the state budget. The largest amount of funds should arrive in 2023 (Figure 2). However, for this it is necessary to find investors.

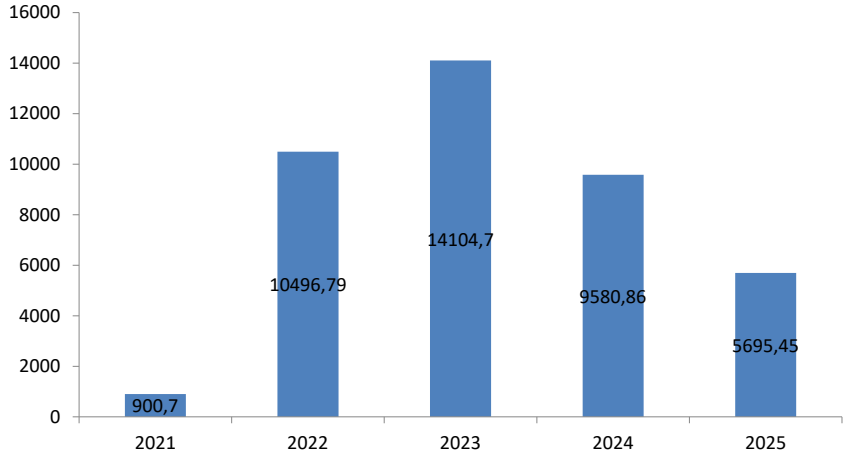

Figure 2. Financing of the space industry by year, billion UAH

Source: systematized by the author [12]

3. The ephemerality of space vehicles RSE. Their average service life is no more than 7 years. Creating new satellites and replacing those that have failed will require significant financial resources, which in turn will cause significant pressure on the state budget.

4. Unprofitability of state-owned enterprises that could be involved in the development of surveillance devices.

5. The lack of a sufficient number of qualified personnel, which is, caused by the unsatisfactory salary of specialists in the space industry.

Ways to solve these problems are, provided in Table 1.

Solving these problems will make it possible to provide Ukraine with extremely important apparatuses for the civil and military sectors, and will contribute to increasing its technology and defense capability.

5. Conclusion

There is no doubt that the domestic space industry is an integral part of global space, as there is scientific, technical and industrial cooperation, the development of the industry involves the development of international projects and programs. Cooperation between Ukraine and foreign countries in the research and use of aerospace space for peaceful purposes takes place

Table 1

Problems of creating space surveillance systems and ways to solve them

Problems	Solutions
Unapproved space program for 2021–2025	Interested parties, namely the State Space Agency, space industry enterprises, and the Ministry of Defense of Ukraine should initiate consideration and approval of the Program by the Verkhovna Rada of Ukraine. Its adoption is extremely important for solving tasks in the field of security and defense of the state
Lack of investors	It is necessary to establish cooperation with countries that have funds and space programs, but cannot create space vehicles on their own
Short-term space vehicles	It is necessary to introduce new technologies that are used by leading technologically developed countries
Unprofitability of state-owned enterprises	It is necessary to involve private companies in the development of earth observation satellites and other space vehicles. State enterprises of the space industry need immediate reorganization
Lack of qualified personnel	It is necessary to review the financial support of specialists in the space industry and create comfortable working conditions. Thus, it is possible to stop their outflow abroad

Source: compiled by the author

on the basis of current legislation and international agreements reached with foreign countries in the space sector.

Observing Earth from space is becoming more and more popular. With the help of space systems, information is, obtained that is, used in various spheres of life: Ecology, Hydrometeorology, Oceanography, Land management. The data received from surveillance satellites is, used in the military sector.

Ukraine, which has everything necessary to create its own remote sensing satellites, is, forced to buy foreign products. At the same time, it has significant prospects for the development of space systems for observing Earth.

In order to activate this process in Ukraine, it is, necessary to approve the National Targeted Scientific and Technical Space Program for 2021–2025, find investors to finance Ukrainian developments inside the country and abroad. Introduce new technologies for creating space surveillance systems, and involve private companies in the work and reorganize State-owned enterprises, ensure decent wages and create comfortable working conditions for domestic specialists.

All this will contribute to the achievement of the goals envisaged by the space program and the revival of the space industry in Ukraine.

In our opinion, it is necessary for the state to regulate the activities of large enterprises, implement comprehensive reforms in this area and invest in its development. In today's conditions, during the period of active development of military operations, there is an urgent need for the development and improvement of own production of space vehicles, complexes and systems, in order to ensure the national security of Ukraine. Without its own production, the space sphere will not be able to get out of the crisis. At the same time, the development of cooperation with the Western world, deep integration into world markets and the attraction of European private capital into the space sphere are also prospects for the development of the space sphere.

It should be noted that outdated approaches to the organization of space activities in Ukraine do not bring the desired result. We see how the world today is being commercialized in the space sphere, so we need to reorganize Ukrainian cosmonautics in order to remain a country with space status.

To date, Ukraine does not have its own spaceport and launch vehicle, which is an urgent issue in solving the issue of the formulation of Ukraine's national security during military operations.

The obtained results are of practical importance. They can be, used in the domestic space industry.

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