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NON-ROCKET SPACE INDUSTRIALIZATION: PROBLEMS, IDEAS, PROJECTS

2019

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ISBN 978-985-451-414-7

Astroengineering Technologies LLC

NON-ROCKET SPACE INDUSTRIALIZATION: PROBLEMS, IDEAS, PROJECTS

Collection of Articles
of the II International Scientific and Technical Conference
(June 21, 2019, Maryina Gorka)

Minsk
PARADOX LLC
2019

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Introduction to the Collection of Articles of the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects"

The world's first conference dedicated to the non-rocket space industrialization was held in the city of Gomel from 26 to 28 April 1988.

At that time I was working as the head of the patent and licensing service at the Institute of Mechanics of Metal-Polymer Systems of the Academy of Sciences of the Byelorussian Soviet Socialist Republic. I joined the Institute in 1978 having left the position of a senior engineer of a construction trust for the position of a simple engineer with a lower salary and worked there for 10 years under the supervision of my mentor and teacher, deputy director of science Yuri Mikhailovich Pleskachevskiy.

The Institute has a remarkable history of its establishment. It was founded as a research group of the best students of one of the Gomel universities, which was then transformed into the Gomel branch of the Laboratory of the Institute of Mechanical Engineering of the Academy of Sciences of the BSSR, and then – into the Mechanical Engineering Department of the Academy, and only 13 years later, by decree of the Council of Ministers the department was transformed into an institute. The founder of the metal-polymer systems mechanics direction, Vladimir Alekseevich Bely, who later became the director of the Institute and academician, acted at times on the verge of law. For example, to get financing in the Soviet planning system, when everything was planned in advance, a deep excavation for the foundation of the future 9-storey building of the Institute was dug at his initiative in the center of Gomel. Imagine the reaction of Gomel Regional Party Committee presented with such a fait accompli. The consequences of such actions for V.A. Bely could have been rather predictable. Today he would be called a cheater and adventurer. To a large extent, I have repeated the path of this Belarusian scientist, however, my path was longer and more thorny.

I organized the first international conference with the support of the Soviet Peace Foundation and the USSR Cosmonautics Federation, of which I am still a member, although such a country has not existed for 28 years. This historical event was attended by about 500 people – engineers


У КОСМАС—
БЕЗ РАКЕТ

and scientists from 20 cities of the USSR. 30 reports and more than 100 presentations were made. The conference was covered by the central Soviet press, the Belarusfilm studio shot a 30-minute popular-science film "In the sky on the wheel", which was shown in cinemas of the USSR and abroad. The film well conveys the atmosphere of the event – an alarming call to humanity to wake up and direct maximum efforts not to the destruction

of the biosphere of the planet, but to the provision of conditions for the preservation of life and sustainable development of our technocratic civilization.

It was this striving that united all the participants and made them come to Gomel. Among them were two cosmonauts: twice Hero of the Soviet Union Yuri Vasilyevich Malyshev and Hero of the Soviet Union Igor Petrovich Volk.

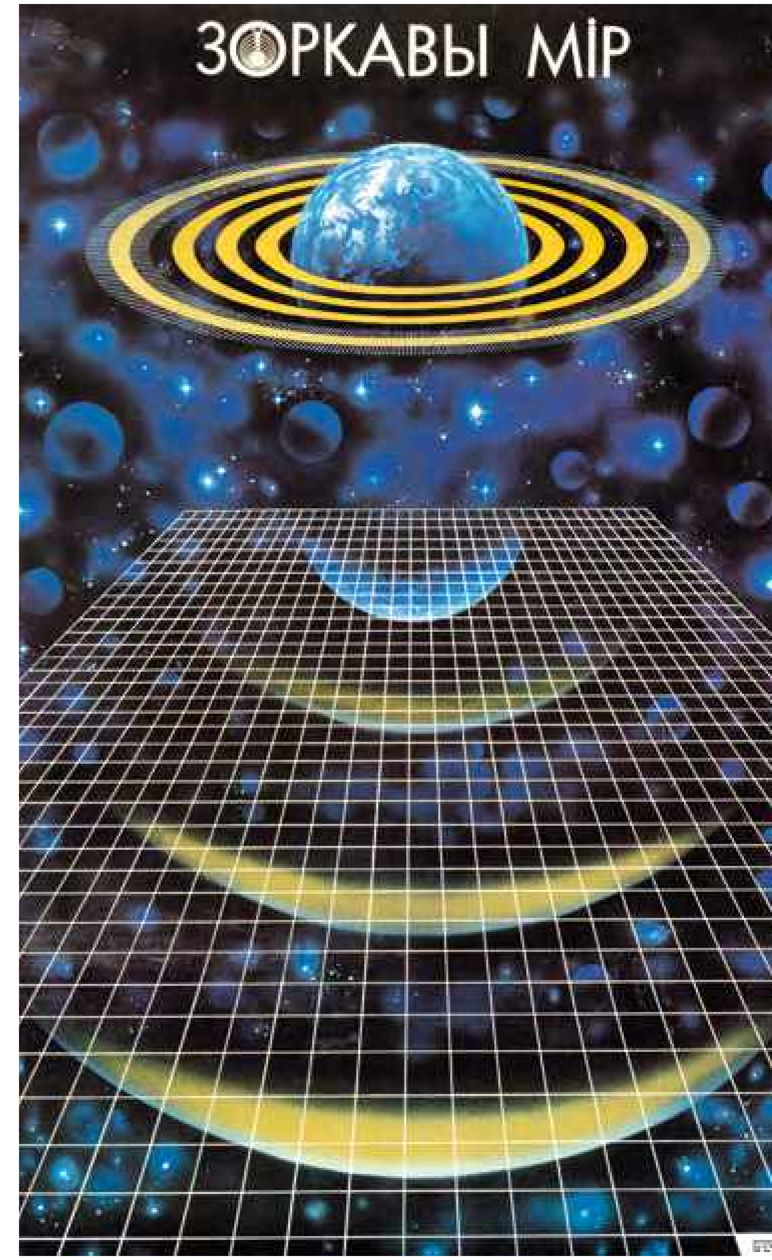
I was a speaker and a supporting speaker on four topics, and my proposed General Planetary Vehicle (GPV) project was in the spotlight of the conference.

GPV is a geocosmic aircraft covering the planet in the equatorial plane. The peculiarity of its functioning is that the launch into space is carried out by increasing the diameter of its ring and achieving at the calculated height (with passengers and cargo) of the circumferential speed of the body, equal to the Earth orbital velocity. At the same time, the position of the center of masses of the GPV does not change in the process of launching into space – it always coincides with the center of mass of the planet. That is why the "Baron Munchausen principle" can be implemented here – the use of the system's internal forces to move within the space without any negative impact on the environment. In this single version, such an aircraft does not contradict the laws of physics.

The optimal internal driving force for GPV is the excess centripetal force from the belt flywheel accelerated around the planet in a vacuum channel with the help of a linear electric motor and a magnetic cushion up to speeds exceeding the Earth orbital velocity – up to 12 km/s, depending on the ratio of linear masses of the body and flywheel. In order to transmit the impulse and the moment of impulse to the GPV body when entering the orbit to obtain an orbital velocity equal to the Earth orbital velocity, a second belt flywheel, also covering the planet, is required.

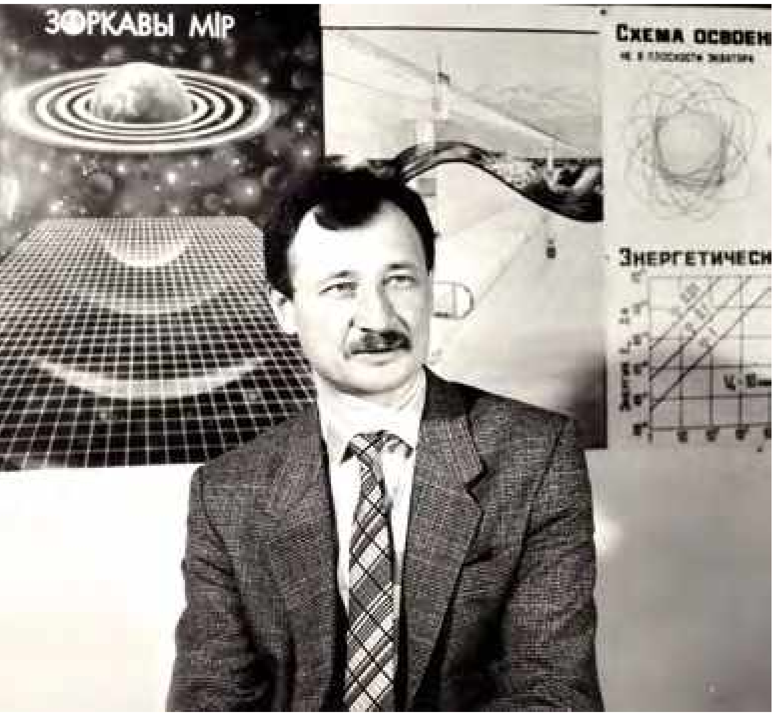
Such a system will be able to put into orbit about 10 million tons of cargo and 10 million passengers for each flight, making up to 100 trips per year. Thus expenses for delivery of each ton of cargo into the orbit in comparison with similar expenses by modern cosmonautics will be reduced in thousand times and will make less than 1,000 USD per ton that will allow providing an access to unlimited spatial, raw and technological resources (weightlessness, vacuum), and also the possibility of removal of harmful manufactures in near space and with its subsequent industrialization. Preserving and increasing its industrial power, humanity will solve most of the environmental problems – this was the main message of that conference in 1988.

As a result of the conference, a decision was made to establish a scientific organization based on the principles



of self-sufficiency and self-financing – the Center "Star World", which could finance the performance of research and development on the General Planetary Vehicle. Thus, an intensive teamwork on the project began.

During a year and a half under my leadership the Center "Star World" registered about 100 innovations, which were introduced at the enterprises of the USSR and brought income of about 5 million USD (a large amount of money at the time!), which allowed to finance various projects within the framework of development of the concept of non-rocket



space industrialization proposed by me. A lot of research has been carried out, the results of which remain relevant even today, and in many industries, we were pioneers. However, due to various circumstances, this work had to be ceased.

Before that year and a half, and after that, as an engineer, designer and scientist, I was all alone, imprisoned in incomprehension for a period that is three times longer than the imprisonment of the Count of Monte Cristo. All these years I worked hard and remained silent until now, when I escaped from this intellectual prison with the help and support of my "Abbé Faria", a faithful friend and assistant, my wife Nadezhda. That is why the second conference was held 31 years later. The time between these two events was a test of viability for the project, and for me personally a period of struggle for the idea and the formation of a solid foundation for its implementation, which was the string transport SkyWay, "budding" from the overpass of the General Planetary Vehicle.

From the very beginning, from the moment of publication of the GPV project, it faced criticism, misunderstanding and rejection – in the State Committee for Inventions of the USSR, then in the Soviet newspapers, in courts, in the offices of the CPSU Central Committee and so on. Most of the time, I was lonely in this fight. There was not much behind my shoulders and no one wanted to believe me. It was necessary to prove that I am right, to show that my engineering ideas are working, the systems offered are effective. 31 years was the time it took to complete this task.

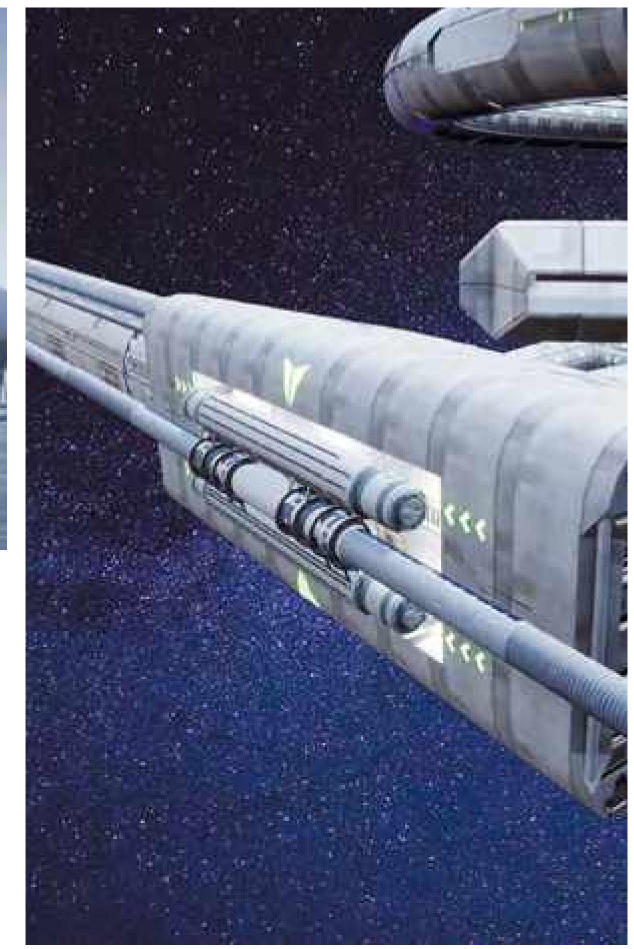
String transport SkyWay is a ground-based overpass communicator, which is embodied, tested and demanded by the market. Today it is considered as the basis for the formation of a new branch of the world economy. Having implemented this project, I proved that I can think through and create complex systems, organize financing, science, design, engineering and production of industry-forming technology. It made many people look differently at the GPV: "If one works, then the other should work too, because both were invented by the same engineer".

After three decades of silence, my like-minded people and I once again began to talk about the danger in which the world is, and the way to save it from a global catastrophe – to create a geocosmic transport of a new generation and the industrialization of outer space, as the only alternative to the degradation and destruction of our technocratic civilization. Otherwise, the dead technosphere created by civilization will finally destroy the living biosphere created by nature, including its "parent" – the wise man (Lat. *Homo sapiens*) – a kind of people (Homo) in the family Hominidae, the order Primates – one of the millions of species of living organisms on our planet, who thought itself the "king of nature".

Cosmonaut Igor Volk, the participant of the first conference, said that when he was in space, his first desire was to destroy people, including himself – so clearly seen from there, what damage we do to the blue planet. Our families were good friends. I remember the long conversations with Igor Petrovich about the future, about space, about taking the Earth's industry beyond the limits of the planet. He told about the damage to the organism of weightlessness and cosmic radiation...

I have not seen the Earth from space, but I have seen the depopulated village Kryuki, my small Homeland, located 7 km from the Chernobyl Atomic Electric Power Station, lost forever for me, my children and grandchildren. If we do not come to our senses, this can happen to all of us, to our common home, the biosphere of planet Earth.

The II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects" summarized the results of research and outlined the direction of further development in the framework of projects aimed at creating a general planetary vehicle and peaceful expansion into space in the name of a safe future for people. It was held in a family way, without special formalities, on the territory of the Unitsky's Farm Enterprise in the town of Maryina Gorka, near SkyWay EcoTechnoPark, built by SkyWay Technologies Co. under my leadership.



A. UNITSKY,
Chairman of the Organizing Committee
of the II International Scientific and Technical Conference
"Non-Rocket Space Industrialization: Problems, Ideas, Projects"

Opening Speech by the Chairman of the Organizing Committee of the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects"

The II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects" was held on June 21, 2019 in Belarus at the place surrounded by the picturesque Belarusian nature. The title of the conference contains three key words: "second", "non-rocket" and "industrialization". It is worth considering them in more detail.

"Second" means there was the first conference. It was held back in 1988 in Gomel, the place where I was born. I managed, being a member of the USSR Cosmonautics Federation, with support of different organizations of the Soviet Union (the Federation itself, Soviet Fund of Peace and All-Union Society "Znanie"), local authorities (Gomel Regional Communist Party Committee and All-Union Lenin Communist Youth Union Regional Committee) as well as of the institution for which I worked as the Head of Patent and Licensing Department (Institute of Mechanics of Metal-Polymer Systems of the Academy of Sciences of the Byelorussian Soviet Socialist Republic), to gather about 500 guests concerned about the fate of the Earth from different countries of the world, the Soviet cosmonauts Yuri Vasilyevich Malyshev and Igor Petrovich Volk were among them.

Yuri Mikhailovich Pleskachevsky, who back in 1988 was Deputy Director for Academic Affairs of the Institute of Mechanics of Metal-Polymer Systems and my line manager took part in the second conference as an honorary guest. He played a significant role 31 year ago in preparation and holding of the first conference mentioned. I was also pleased to welcome one more participant of the first conference: Sergey Victorovich Shilko, who later on the basis of results of the presented reports assisted me in preparing my first research monograph "String transport systems: on Earth and in space", published in 1995. I would like to express my sincere thanks to them for support in continuation of the journey, which started 31 year ago.

The second term **"non-rocket"** emphasizes that the rocket is not considered the main geospace vehicle for wide-scale near space exploration. This may be explained by two main reasons. Firstly, low performance coefficient, about 1 % and extremely high temperatures and speed of ejection of the jet stream into the atmosphere, which in case of the frequent launches, totally about 100 per year, could cause significant damage to the nature and environment of the Earth, even the complete destruction of the ozone layer. Secondly, even daily launches of the heavy rockets would not provide the required passenger and cargo traffic: the volume of geospace transportation in any case will be extremely small – less than one gram per each citizen of the Earth.

The third important part of the title is **"industrialization"**, which means that the reports delivered at the conference addressed only the matters which would exactly provide the industrialization of space instead of its scientific research as it is happening now in the world. The reason is very simple: the human civilization of Earth is technocratic, i.e. mostly based on the industry, and this vector of our existence and development will remain unchanged in the future as well, as the only possible way for our children and grandchildren.

Thus, the title of the conference reflects the so called "highway" – the main route of development for our Earth's technocratic civilization – and in this sense it is comprehensive enough and should not be changed in the future. The only closer definition of the title for the third and further conferences should be the following – "industrialization of the **near** space", which would be followed by expansion of the industry to the extent of the entire Solar System and then to the Milky Way, but this will take a longer period: the XXII century and later, but under no circumstances – the XXI century.

It is obvious that our civilization should move forward to reach the progress step by step, from one level to another, and in no case miss any of them, as it is seen by some futurologists calling for industrial exploitation of the Moon and Mars located at the distance of hundred thousand and even hundred million kilometers. Please ask yourself a question: what will be the cost of the products produced there and how long would it take to deliver for example fresh fruits from Mars to the Earth. And would they grow there? The reports delivered at our conference also contain the answers to these questions. For example, in accordance with the SpaceWay programme, the industrial and agricultural products produced in the Industrial Space Necklace "Orbit" located in the equatorial plane at the altitude of some hundreds kilometers will be cheaper than those ones produced on the Earth.

The first reports at the conference were delivered by A. Unitsky, the engineer, author and designer of the General Planetary Vehicle and the SpaceWay and EcoSpace programs, who now is and during many decades has been the only sponsor and investor of these projects.

I would like to attract your attention to one more fact: most of the authors in this collection of scientific articles are young scientists. They take part in the events of similar nature for the first time. They are young not only from the point of view of their age, but also because they are researchers of the engineering and not the scientific organization: SkyWay Technologies Co. I am sure that their writing attempts will be successful and the articles of these and many other authors will be published on a regular basis in collections of scientific articles of further conferences.

A. UNITSKY,
Founder and General Designer
of Astroengineering Technologies LLC,
Doctor of Philosophy in Transport,
Member of the USSR Cosmonautics Association

Welcome Speech by the Vice-Chairman of the Organizing Committee of the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects"

I want to express my deep gratitude to Anatoli Unitsky, the organizers of the conference and all the participants. It is a great honour for me to be a part of such a significant event.

What Anatoli Eduardovich wrote about 40 years ago – the non-rocket exploration of outer space – not only did not lose its relevance, but also acquired even greater significance for our civilization in new realities. Engineer Unitsky is seriously involved in the space industry issues and at the same time deeply cares about the environment.

Today, our planet is overtaken by military conflicts and other disasters, therefore, Anatoli Unitsky's inventions, designed to unite people, point the way to peace and prosperity, are very valuable. Space is what has always united us. Because space is humanity, space is us, our children, everything around us. At the present stage of development of astronautic science, it is impossible to abandon rocket launches, and we understand this. However, it is right now that the foundation of our common future should be laid, and it lies with such promising projects as the General Planetary Vehicle.

Every Earthling needs transport systems on which Anatoli Eduardovich works. They may be the only opportunity for the survival of our civilization. The GPV project implementation will allow humanity to exist in harmony with nature. While we were only wondering about environmental issues, Anatoli Unitsky had already presented a ready-made solution to society. He does things that are difficult to imagine.

I believe in my friend and countryman, in his talent, I am confident in his calculations. I believe that everything is within the men's control, nothing is impossible for men. Therefore, everything is in our hands – our life and the life of our children. And the fate of the Earth is also in our hands.

P. KLIMUK,
pilot-cosmonaut of the USSR,
twice Hero of the Soviet Union,
Colonel-General of Aviation of the Russian Federation,
Doctor of Engineering Science, Professor,
Honorary Member of the National Academy of Sciences of Belarus

Opening Speech by the Vice-Chairman of the Organizing Committee of the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects"

I am very pleased to see that this event has gathered so many young people. I immediately recall the first conference. As a participant of both conferences, I can judge the dynamics of the event, I see how human interest in space has grown, but I also understand the low efficiency of rocket space exploration and together with this a stronger public interest is in alternative programs such as Anatoli Unitsky's SpaceWay. I'd like to note that over 31 years after the first conference, a lot of work has been done. Calculations were carried out, a team was assembled, prototypes were built.

Anatoli Unitsky is a unique person who, despite various difficulties, did not give up and continues to proceed to his goal. It seems that the difficulties only discipline him, make him summon up. A colossal achievement of his persistence was the string transport. I understand that all this would not have happened without the contribution of a huge number of Unitsky's engineers, designers, like-minded people, but there could not have been string transport without Unitsky. And today it is no longer posters and models – it is a reality. Just a hundred meters from the place of our meeting, there is a completed proving ground – EcoTechnoPark, where Unibikes, Unibuses and Uniwinds are in operation, capturing imagination.

Now the turn for SpaceWay has come. All those present probably know that the attitude of the general public to SpaceWay project was mixed throughout the time. But I'd like to tell that it has never happened across the world that ideas of this level were accepted by society at once. There have always been more critics than creative people. Even the great Russian scientist Mikhail Lomonosov noted: "No great mind is necessary to criticize others. Giving something better is what a decent person shall do." Unfortunately, own thoughts are expressed more and more seldom. But sometimes the world gives us people like Unitsky. Such people are idea generators – they are supporting the world, they are developing engineering and technologies.

Before rising to the podium, I remembered and wrote down the key words that were voiced at both conferences. Last chance. The only way. Rescue scenario. In the name of a common goal. These words scare, but these notions exist in new realities, which human has created himself. The speed with which we roll down into the abyss is even more striking than the indifference of others. We must understand that further progress is not the responsibility of individuals, scientists, engineers; it is a hard work, where everything will depend only on us, on civil society.

The program of the conference includes a number of presentations dedicated to environmental problems and their solutions, they touch upon the issues that can no longer be ignored. And what is important, today we have all technical and technological prerequisites to prevent a catastrophe of a global scale. Suffice it for the society to discover the strength to listen to the voice of reason and support the ambitious projects that Anatoli Unitsky offers us. We still have a chance. And I think we should hold on to it.

YU. PLESKACHEVSKIY,
Corresponding Member
of the National Academy of Sciences of Belarus,
Doctor of Engineering, Professor,
Honored Scientist of the Republic of Belarus

Opening Speech by the Co-Chairman of the Organizing Committee of the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects"

When I was invited to the conference, I decided that I would prepare my report on financing and strategies, but Anatoli Unitsky said, "Let it be a free speech, like a conversation in the kitchen." And then I decided that I would tell you how this whole story began for me and how I got into this project.

Today, we, the human race, consume more resources than our planet can produce. We burn in seconds coal, oil and gas that took millions of years to appear. And the appetites of the techno-civilization are constantly growing. Of course we all know about it. And I knew it, too, but like most people, I tried not to notice it. People generally tend to hide their heads in the sand, but sooner or later we have to admit our mistakes and start to fix them.

One evening in Dubai Anatoli Unitsky talked about his Skyway and SpaceWay projects. I listened carefully. He explained how you can transfer all the production facilities beyond the Earth, into outer space, and it seemed to me fantastic. And at the end of his speech, he said, "If we cannot implement this project – our whole world will pass away." I remembered that night, which made a revolution in my mind.

Many of us often ask ourselves, "Well, this is a common responsibility, why should I decide anything?". However, a completely different idea came to my mind, I thought, "Okay. It's just a matter of money. We need about $2.5 trillion. This is the amount of lift. If you count, you get somewhat 400 dollars from each resident of the Earth". But at the same time there came the realization of how many challenges should be solved. If you looked at the map of the world, you should know that wherever we look, wherever we point, the whole world is in trouble: war, hunger, poverty. Many people do not even have normal drinking water. And what's worse, we did all this ourselves. We change nature, and then we fight with the consequences of the cataclysms that we have produced ourselves. Over the past 200 years, we have caused a great damage to the planet. As Anatoli Unitsky often says, "We live in debt, at the expense of future generations." It's time to break this circle.

This conference with the works presented and the enthusiasm of the participants testify that we are approaching the implementation of SpaceWay, a grand project that can not only give a chance for the future, but also unite the world. SpaceWay is the only way. That's why I'm here, I made a decision for myself. I have no other choice. And you decide for yourself!

BAPI DASH,
Chief Financial Officer, SkyWay Group

Opening Speech by a Member of the Organizing Committee of the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects"

I am very happy to visit Belarus again, this beautiful country.

I came from Sharjah, the third largest city of the Arab Emirates. Our ruler, His Highness Dr. Sultan bin Muhammad al-Qasimi pays great attention to the development of science, culture and education in the region. He supports innovative ideas, including SkyWay project.

Today, there are many problems in science, including the problem of communication both within the scientific community and the problem of interaction between the scientific environment and public institutions. Lack of communication at different levels hinders progress, does not allow us to implement innovations in production promptly. Therefore, I would like to focus my speech on the issues of communication.

How can we establish communication between the academics of scientific community; between science and government; finally, between science, government and the private sector? For many, the idea of such connections seems to be something trivial, but for me and for visionaries like Dr. Unitsky, it is the biggest challenge. When I first transitioned from business to academic issues, this problem was not obvious to me. But then I saw what a big gap that formed in communication in all areas. And my message, which I'd like to convey to you today, is the need to strengthen ties between the government, science and business. I am sure that this is the key to the success and implementation of many scientific projects.

I really liked the speech by Dr. Unitsky about the role of society in the implementation of innovative projects such as SkyWay and SpaceWay. I was pleasantly surprised how much the society here in Belarus is involved in solving global problems.

Some 40 years ago Anatoli Unitsky developed a program that is designed to solve many problems at once: to mitigate the consequences of human activity, improve the environment of life, to establish communication at all levels. I learned about the SkyWay project, which has great potential for the Arab Emirates and the world, two years ago only. Then I immediately thought it was a very good idea. I still think so.

As you know, over just half a century, the Arab Emirates have become a center of economic, financial and technological development. And we would like to remain at the forefront of progress and innovation, therefore we decided that cooperation with SkyWay is an excellent solution for our country. I see a huge potential in our cooperation and business partnership. And I hope that in the future the communication between scientists of Belarus and the Arab Emirates will grow stronger.

HUSSAIN AL MAHMOUDI,
CEO of the American University of Sharjah Enterprises (AUSE) and of the Sharjah Research Technology and Innovation Park

UDC 629.78

Historical background of the SpaceWay program as the only way to sustainable development of the technocratic civilization

A. UNITSKY (Minsk)

The article discusses the problem of global changes in the Earth biosphere as a result of the existence of a technocratic civilization in the historical retrospective. The author focuses on the fact that modern rocket methods of space exploration cause significant damage to the environment, besides such methods are ineffective from an economic point of view. The author justifies the only possible solution: removal of the hazardous industry beyond the biosphere, and at the same time the brand new geocosmic transport based on environmentally friendly and efficient technology is proposed.

Keywords:
technocratic civilization, ecology, biosphere,
geocosmic transport, SpaceWay, space industrialization.

According to current estimates, there are about 14,000,000 species of living beings on the Earth nowadays [1]. Moreover, the number of described species, i.e. known to science is 1,750,000 – this is only 12.5 % of the estimated.

Every hour about three species of living creatures disappear from the Earth, i.e. more than 70 species extinct daily – more than 26,000 per year [2]. Some of them extinct due to the natural reasons (that is how the evolution works), but most living creatures extinct due to anthropogenous factors. These species disappear from the planet for ever, that is irretrievable. But the nature has created these forms of life not for extinguishing by someone. They are unique – the most state of the art engineering decisions are a far cry from the pieces of the Creator's technology.

Not only any living creature, not only any of its organ or any of its single cell are unimaginably complex, but even its single tiny "brick" – a DNA macromolecule that contains genetic information (a man has about 100,000 of genes) – is hundreds of thousands times more complex than for example a Boeing. An aircraft is composed of several millions of parts, this organic macromolecule contains hundreds of billions of "parts" – atoms of dozens of chemical elements from the periodic table, structured into an unusually complex and reliable structure, proven by millions of years of evolution, and also capable of self-reproduction.

The number of cases of allergies, cancer, lung and cardiovascular diseases, as well as genetic disorders and hereditary human diseases caused by water, air and soil pollution is growing rapidly on our planet.

There are irreversible changes in the landscape and soils; forests disappear; rivers, seas and oceans become polluted; the ozone layer, which protects all living beings from the destructive hard radiation of the Sun, is intensively depleted.

There are many causes of negative changes in the biosphere of the Earth, but what is the primary cause of these processes? Only by understanding this, one can avoid the degradation of the biosphere and the humankind as one of the biological species, and also determine the ways to harmonious development of our earth techno civilization in the future.

According to the modern concepts, life originated on the Earth about 4 billion years ago. While developing and adapting to the conditions that existed on the planet in those times, living organisms began to transform the environment. These transformations were as great as those that occurred with living organisms as they developed and improved. Thus, the oxygen-containing atmosphere appeared on the planet which was dead and desert in the beginning, as well as living fertile soil, coral islands, the ozone layer, the modern natural landscape with its savannas and forest-steppes, swamps and tundra, taiga and jungle appeared. Thus the biosphere appeared, where millions of species of living organisms and the planet transformed by them over billions of years are ideally "fitted" to each other. And there is nothing superfluous in the biosphere.

One should paid special attention to the fact that the entire biosphere of the Blue Planet is created from the waste and on the basis of waste produced by living organisms. Oxygen and, accordingly, ozone are waste of photosynthetic bacteria and green plants; fertile soil and humus – all of these died at one time and passed through someone's stomach and intestines, including soil microorganisms and earth worms.

But then a man appeared, who owing to his mind, began to strengthen the power of his muscles, organs of sense and intelligence, began to create technologies, began to master technological processes. This happened a long time ago, hundreds of thousands of years ago, when primitive people just began to manufacture the first primitive tools, and then began to cook food on the fire, to process animal skins in their home – the cave. And they died of lung cancer at the age of 20 as there was smog in their houses. But they survived as they guessed of removing technologies from their home to the environment – the biosphere. And the planet's biosphere has become a home for the nascent civilization, not even a home, but a single room that does not have partitions.

It was then that the humankind chose the technological way of development, and we cannot change it today. The modern industrial power of the Earth's civilization is only a logical development of a technocratic way. Homo Sapiens, having united into local societies, and then, when industry emerged, into a planetary civilization, has now become qualitatively different - Homo Technocraticus[1].

In the twenty-first century the Homo Technocraticus actually narrowed down to the concept of the "Asphalt man", since most people began to live in cities. And there is a huge area that is "covered by asphalt" on our planet – the size of this area equal to the area of five Great Britains. This soil is dead, it does not have green plants on it that produce oxygen necessary for human breathing. The soils situated in areas which are 10 times larger and adjacent to roads are degraded and polluted with carcinogens from exhaust gases and tire wear as well as asphalt products.

The world's roads which are more than 30,000,000 km long, annually kill about 1.5 million people on the planet and make much more people disabled and crippled [3, 4]. Moreover, traffic accidents are the eighth leading cause of death worldwide and, most importantly, the main cause of death for children aged 5–14 years and young people aged 15–29 years. And how many billions of animals, domestic and wild, large and small, they kill - no one even knows. Cars burn more than 2.2 billion tons of fuel annually, passing more than 35 billion tons of life-giving air through high-temperature combustion, burning more than 7 billion tons of oxygen out of the atmosphere [5]. This amount of oxygen is produced, for example, by pine forest covering an area of 240 million hectares per year.

Plants, factories, power stations, machine tools, automobiles and other engineering equipment of the technosphere created by techno-human are analogues of living organisms in the biosphere [6]. And they, like living organisms, exchange energy, information and matter with the environment, therefore, like organisms, they must inevitably transform the surrounding Nature.

Technogenic pollution of the environment occurs only from the point of view of biology. From a technical point of view, machines, factories, plants, power stations and transport vehicles do not pollute anything. At the entrance they have raw materials, at the exit – the finished product or service, for example, energy, information or transport, and the converted raw materials (excluding the finished product or service), which, naturally, goes to the same place

[1] The term "Technocratic Man", in Latin it is "*Homo Technocraticus*", was used to describe mind in the common sense, as "mercantile man". Initially, "mercantile" meant "commercial", and the expression "mercantile person" meant a "good businessman". The "technocratic man" was supposed to be the next stage in the qualitative development of "Homo sapiens", but technocratic tyranny shows the opposite - regression.

where it was taken from, - to the environment. To avoid this is impossible in principle. It is also fundamentally impossible to create closed, absolutely "green" engineering technological cycles that environmentalists dream of in order to solve all environmental problems on the planet in this way. This is about the same as looking for a way to ban a cow, along with the products we need (meat and milk), to produce waste as well – urine, manure, methane and CO_2.

Even the biosphere as a whole cannot be called a closed system. It is an open system and that is why it transformed the previously dead Earth. Only an Earth-Biosphere system is closed. But even this system is not completely closed, since it absorbs the energy of the Sun and cosmic radiation, cosmic dust and meteoritic matter and radiates technogenic light into outer space at night and it produces radio emission 24/7.

Even the whole technosphere, and not a single machine, factory or plant in a single taken planet cannot be a closed system. The technosphere will inevitably transform the planet and its biosphere. But which way?

Technosphere does not need an oxygen-containing atmosphere[2]. Therefore, for example, today the industry and transport of the USA already consume more oxygen than its green plants produce on the territory of this country. Americans live in debt. They consume oxygen produced by the Russian taiga and the Amazon jungle.

The technosphere also does not need alive fertile soil. Therefore, the planet has less and less fertile lands, and more and more dumps, slag, ash and terricones. But a healthy fertile soil, such as chernozem, in a kilogram of which about a trillion microorganisms of several thousands of species live, is inherently the immune system of the entire earth's biosphere. This is where the food chain begins for most living organisms on the planet and all viral diseases, including the most deadly ones, end here.

It is microorganisms each type of which has its own specialization[3] that create universal nutrition for plants – humus, all sorts of insoluble humic acid salts, otherwise rain and groundwaters would wash out all plant food from the soil. Other types of microorganisms "open" this original canned food - organic compounds, which contain the entire set of chemical elements necessary for life (about 80 from the periodic table) in the form of thousands of specific and very complex organic compounds (and not simple chemical compounds, such as chemical fertilizers), i.e. the humus is converted into a soluble form and thus the plants are fed.

But a man began to kill the soil microflora and microfauna, that is the immune system of the biosphere, by plowing and mineral fertilizers, herbicides and pesticides, asphalt and terricones. And very soon the biosphere of the planet will become like an AIDS patient with a weakened immune system[4], that can "die" from previously harmless "disease".

Acid rains, smog, increased levels of radiation, destruction of the ozone layer of the planet, etc. – all these things are consequences of the industry existence. It is possible only to slow down the process of transformation of the earth nature and the biosphere, but it cannot be stopped. The technosphere occupies the same ecological niche as the biosphere itself: machines, transport vehicles, mechanisms, technical devices are located in the midst of the earth, water, air and actively interact with them.

Environmental problems have recently become aggravated only because the power supply capacity of technosphere (i.e. its capacity to transform the environment) has approached to the biosphere on the whole. For example, in the process of photosynthesis, the biosphere now reproduces about 150 billion tons of dry organic matter per year [7], which, in terms of fuel, is only by an order of magnitude more than the annual energy consumption of all the equipment available to our civilization. And the volumes of soil, coal, ore and other types of raw materials transported and processed by various equipment are already very close to the volume of production of organic matter in the biosphere.

From a biological point of view, the humankind as a species of living beings is a "child", whom the biosphere "gave birth to", with a total biomass of about 500 million tons (about 350 million tons of these 500 tons are water). And it does not pose any danger to planetary ecology as a total mass of living matter in the biosphere is about 2.5 trillion tons (of which about 1.8 trillion tons are water) and the mass of the mankind is less than 0.02 % of it. So metabolism and homeostasis of civilization as a community of people, as an open biological system, are less significant for the planet's biosphere than any mold that has a larger total mass.

Global problems are actually created by the homeostasis of a completely different "child" – the one that was born by Homo Technocraticus. And this "child" is called – the industry. It grows very quickly, his appetite is steadily increasing, and its mass (in many respects it is useless "industrial fat") approaches the mass of living matter on the planet.

Recently another culprit of global warming has been discovered – a Bitcoin. The cost of electricity to maintain a non-optimal Bitcoin payment system already accounts for about 1 % of the total world energy. One transaction requires as much energy as an average family spends per month in the Netherlands. If the growth rates remain and the essence of this non-optimal information technology does not change, then in the short term perspective, mining will consume up to 100 % of the global electricity production [8].

Thus, not only material substances associated with the processing, but also information technologies are causing more and more tangible environmental damage. Although the information itself is not material, it is stored and processed on tangible media, and that in fact creates environmental problems.

There is only one cardinal way out of the current situation: it is necessary to provide the technosphere with an ecological niche outside the biosphere. This will ensure

2 For technical needs oxygen is irreversibly taken mainly only from the atmosphere, for example during the combustion of fuel in automobile engines. And the only reason for using this method is that it is the cheapest one and not the only possible one. In the absence of oxygen in the atmosphere the cars would work perfectly well if in addition to the tank with fuel there would be also a tank with an oxidizer – the mentioned oxygen.

3 To create all technological diversity that makes up the modern industry, Homo Technocraticus has invented thousands of professions and specialities: a locksmith, plumber, electrician, turner, welding operator, driver, writer, manager, etc. However, there are much more "specialities" in nature and its base – microorganisms, including soil microorganisms. Some of them work for example with nitrogen, turning it into the compounds that plants can assimilate, others – with phosphorus, some of them work with selenium, some work with iodine, some produce oxygen, etc.

4 The main part of the human immune system is located in the intestines where trillions of microorganism of numerous kinds reside. Mainly they are soil microorganisms and they feed, water and cure us. Some experts consider the intestines to be our second brain.

the preservation and development of the biosphere according to the laws and directions that have been formed during billions of years of evolution, as well as this will ensure harmonious interaction of the people community (as biological objects) with the biosphere.

There is no such ecological niche for the technosphere on the Earth. But there is such a niche in near space, at a distance of 300–500 km from the surface of the planet, where ideal conditions exist for most technological processes: weightlessness, vacuum, ultrahigh and cryogenic temperatures, unlimited raw materials, energy and spatial resources, etc.

Thus, the conclusion is that it is necessary to industrialize space if in the future the earth civilization will continue following the technological way of development[5]. The mankind doesn't have much time for the large-scale space exploration – according to a variety of predictions, due to the technocratic oppression of the biosphere, its irreversible degradation, and correspondently degradation of the human race, will begin in two generations. This will become the point of no return for the technocratic civilization of the earth type – no measures will help it to turn back.

The humankind has no experience in the near-Earth space industrialization. And what should be the space industry? What are its functions, what are the volumes and types of the goods produced? Where will these products be mainly consumed: in the space or on the Earth? There are a lot of questions. And there are no clear answers today. Any answer can be the right and wrong one at the same time as everything will depend on those specific development ways concerning large-scale space exploration chosen by the earth civilizations in the future.

Indeed, the abovementioned objective reasons (environmental constraints, exhaustion of the earth's raw materials, energy, spatial and other resources, the danger of overheating of the atmosphere and global adverse climate changes, etc.) should remove the sphere of material production almost entirely into the space in the future. At the same time, humans as a biological species, like any other species of living organisms on our planet, are the product of 4 billion years of evolution under the earth's conditions.

[5] Apparently there is no other way for the mankind as the technological way of development has reached a high level. And it has raised living standards and ensured the existence of more than 7 billion of people on the planet. In case of refusal from industrial power of our civilization, billions of people can die (from starving, diseases, cold, etc.) (The blockaded Leningrad during the Great Patriotic War can serve as an analogue of such a situation).

We are ideally "tailored" to the earth's gravity, to the magnetic and electric fields of the earth, to the earth's air saturated with phytoncides of flowering plants, to the earth's spring water containing the microelements we need, to earth foods grown on the earth's fertile soil, and much more earth's things we do not even suspect about, but without which we cannot exist not only today, but also in the foreseeable future. There are no place in the vast universe for us, people of Earth, more suitable than our beautiful Blue Planet. Therefore, the main consumers of future space industry products, and this is about 10 billion people, will be on the Earth[6].

Space industrialization means creation of conditions on orbit for production of various materials, energy, machines, obtaining new information, implementation of technological processes and scientific experiments. Consequently, significant traffic is inevitable between the consumer of material products – humans living on the planet - and the production of these products placed on the earth orbit as close as possible to the consumer in order to improve geocosmic logistics.

[6] Certainly, having mastered the outer space as a new habitat with conditions fundamentally different from those on the earth, some part of humans who would wish to live in space will eventually be able to transform themselves to fit these conditions (unlike fish, in prehistoric times that came out to land, which eventually led to the appearance a man on the planet, the cosmic man will consciously evolve). But this is too remote perspective and it is not considered in the present work.

Since a human being is primarily material, his consumption of products, both supporting his life (food, water, air, etc.), and industrial (a telephone, computer, refrigerator, TV, car, etc.) is related to his anthropometric characteristic: size (average height of a person is 1.65 m) and body weight (average 62 kg). Therefore, the annual per capita consumption of industrial products in the future should be commensurate with the mass of a man. For 10 billion of people, this figure is at least 100 million tons per year, or 10 kg per individual.

The bottleneck of the coming space industrialization, when the Earth civilization can become a truly cosmic one, is geocosmic transport. Even according to the most ambitious forecasts, the well-known geocosmic transport systems (launch vehicles, space elevator, electromagnetic gun, etc.) are capable of transporting only a few thousand tons of cargo per year along the Earth-Orbit-Earth route, which is tens of thousands of times less than it is required – less than one gram per each inhabitant of the planet per year.

If we were, for example, a civilization of micro-lilliputians and weighed about one gram, then such volume of transportation would suit us perfectly. But for a civilization of the earth's type this is unacceptable. If solutions to this problem will not be found in the near future, our Earth's technocratic civilization will suffer the same fate as mold in a Petri dish: after having eaten all the limited resources and having poisoned the limited space with its waste products, it will die. It is only a matter of time, but it will happen, sooner or later.

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UDC 629.78

SpaceWay program as the only possible scenario to save the earthly technocratic civilization from extinction and death

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The article studies the issue of adverse environmental situation on the Earth, searches the causes and the ways to prevent the global catastrophe of modern humanity. The author believes (and convincingly proves) that moving of the environmentally hazardous industries to the near-Earth orbit will serve a good preventive measure. In this article the continuous intensive cargo traffic on the route Earth – Orbit – Earth is described. The evidence of harmfulness of the existing rocket transport for the Earth's biosphere is demonstrated. As a result of the study, 10 requirements are formulated to be met by the geocosmic transport (GCT), which ideally suits for creation of the space industry, and besides an optimal variant of such a GCT is offered.

Keywords:
technocratic civilization, environment, biosphere, geocosmic transport, SpaceWay, space industrialization.

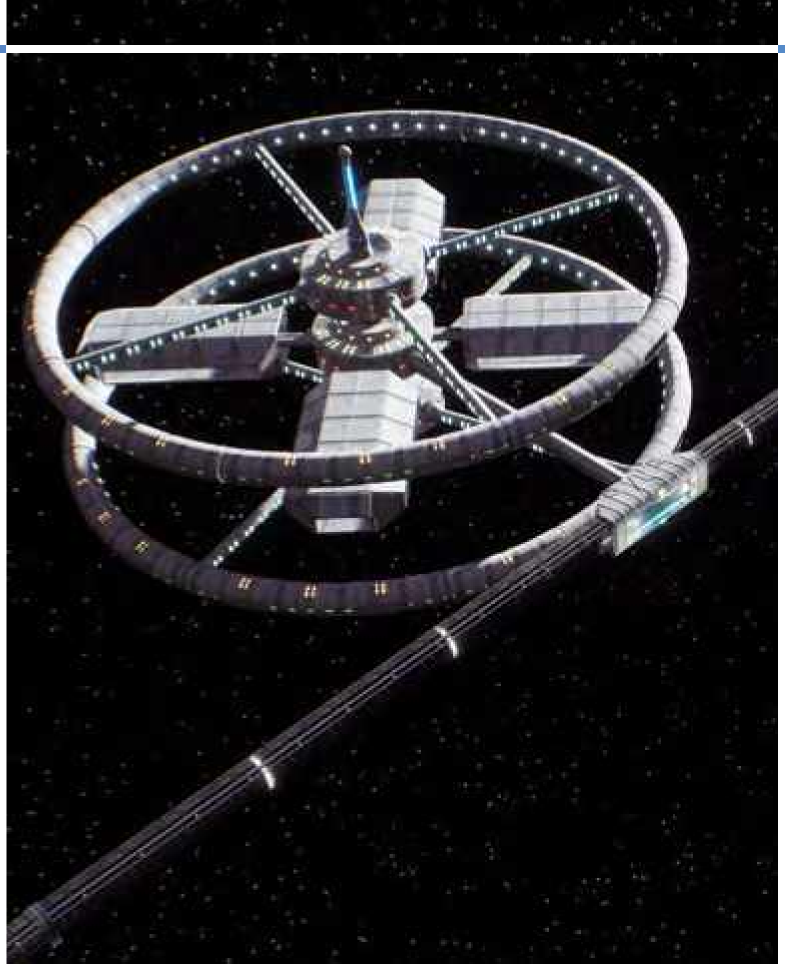
The humankind has no experience in the industrial development of the near-Earth space. And what should the space industry be like? What are its functions, volumes and types of products to be produced? Where will these products be mainly consumed: in space or on the Earth? There could be asked a lot of questions. And people could not give clear answers today. Any answer can be right and wrong at the same time: everything will depend on those particular ways of development to be selected by the earth's civilization in the future during the large-scale space exploration.

In fact, such objective reasons as the environmental restrictions, destruction and degradation of the living fertile soils, exhaustion of the Earth's raw materials, energy, spatial and other resources, the threat of the atmosphere overheating and the global adverse climate change, etc., should almost entirely move the material production sphere to the near space in the future. At the same time, the humankind as a biological species, like any other species of living organisms on our planet, is the product of 4 billion years evolution in the unique and special terrestrial conditions.

We ideally "fit" the Earth's gravity, the magnetic and electric fields of the Earth, air saturated with phytoncides from the flowering plants, the spring water containing the trace elements we need, life-giving foods grown on fertile soil, which is the immune system of the terrestrial biosphere, and still many other things we don't even suspect, but without which we cannot exist not only today, but also in the foreseeable future. Nowhere in the immense universe, including the Moon and Mars, there can be no more suitable conditions for us, the earthlings, than on our beautiful Blue Planet. Therefore, the main consumer of the future space industry products will be located on the Earth[1].

Space industrialization means creation on the orbit of the conditions for production of various materials, energy, equipment, obtaining new information, carrying out technological processes, conducting scientific experiments. Therefore, a significant freight traffic is inevitable between the consumer of the material products (the humanity living on the Earth) and the production of these products placed on the near-Earth orbit.

[1] Having conquered the outer space as the new living environment with the conditions fundamentally different from those on the Earth, a part of the humankind wishing to live in the space would certainly eventually be able to survive changes under these conditions (unlike the fish, which came to the land in the prehistoric times, which resulted in appearance of a human being on the planet, the cosmic man will evolve consciously). But this is too remote a perspective and it is not to be considered in this work.



Since a person is primarily material, his consumption of the products for his own life necessities (food, water, air, etc.) and of the industrial goods rising the comfort level of his existence (telephone, computer, TV, refrigerator, car, etc.) depends on his ergonomics: size (average height of a human being is 1.65 m) and body weight (an average of 62 kg).

It is geocosmic cargo traffic that will determine the pace of development of the space industry for the benefit of the Earth's civilization living in their home on the planet Earth amounting to about 10 billion people by that time. It's like an industrial umbilical cord connecting a growing child with a mother; its cross section will determine the metabolism, energy and growth rate of the child. The mouse has a thin umbilical cord, it is thicker in a man, and even more thick in an elephant. Consequently, the annual per capita consumption of the industrial products in the future should be commensurate with the mass of a person. Thus, for 10 billion people, it is at least 100 million tons per one year, or 10 kg per one person on the planet.

That is why the bottleneck of the future space industrialization, when the Earth's civilization could turn into a truly space civilization, will be the transport on the route Planet – Near space – Planet.

Even in the most daring forecasts, such well-known geocosmic transport systems as rocket carriers, space elevator, electromagnetic gun, etc., are capable of transporting only a few thousand tons of cargo per year, or less than one gram of space production per an inhabitant of the planet, which is four times less than required. If we were a civilization of micro-lilliputs and weighed within one gram, such transportation capacity would suit us perfectly. However, it is unacceptable for the technocratic civilization of the earth type, which smelts today about 2 billion tons per year of only the basic metals (iron, copper and aluminum).

If solutions to this problem are not found in the nearest future, our earth's technocratic civilization will face the fate of the mold in the Petri dish: it will die after having eaten all the limited resources and having poisoned the limited space with its waste products. The analysis shows that only two generations remain until the point of no return, when the industrial technosphere created by a man finally "wins", i.e. finally "kills" the Earth's biosphere [1].

Today and in the foreseeable future the geocosmic transportation will be very expensive: at least 1 million USD/t, taking into account the capital and operating costs in the most ambitious forecasts. Therefore, to implement the space industrialization program, if we rely on the existing and prospective geocosmic transport systems, an annual budget of at least 100 trillion USD will be required, which is unjustified and simply insane costs for the humanity, significantly exceeding the today's global GDP. These costs are actually aimed at the civilization suicide, since almost 100 % of funds will be spent on creating the tools for the largescale destruction of the biosphere by the geocosmic transport system (GCTS), which is especially evident on the example of launch vehicles, including the promising ones.

The environmental harm of the rockets is worth mentioning separately, since it is the rocket vector of space industrialization and exploration of the Moon and Mars, that is considered the most priority by the experts today. Although the rockets, along with the ozone holes, create ionospheric holes with a stream of high-energy particles directed to the surface of the planet, cause turbulence in the upper atmosphere, provoke powerful atmospheric cyclones, drastically reduce the atmospheric pressure at the surface of the Earth, etc., we will consider only one special question: the destruction of the ozone layer.

Back in the early 80s of the last century, there was evidence that more than 60 % of ozone in the ozone layer of the planet was destroyed in the process of rocket launches. A "Shuttle" of the shuttle type in one launch (depending on the ionospheric conditions) can destroy from 10 to 40 million tons of ozone [2], not only because it uses ozone-extinguishing elements as fuel (nitrogen, chlorine, etc.), but also because the plasma of a jet stream has a temperature of about 4,000 °C (almost three times the steel melting temperature) and an outflow speed of about 4 km/s (five times higher than the speed of a sniper rifle bullet). Thus, almost all the energy from the burning fuel in a jet engine is released into the atmosphere, and only a small part of it is spent on useful work: to lift the cargo to the height of the orbit and its acceleration to the orbital speed (the first space one for this orbit).

In addition to the ozone quenching, the rocket launches also change the physical chemistry of the upper atmosphere, cause turbulence in the ionosphere, and even affect the geomagnetic field in the launch pitch plane.

It is difficult to determine the complex economic damage caused to the planetary ecosystem through the traditional rocket space exploration, but a private assessment

of damage only from destruction of the ozone layer of the planet can be performed, if the cost of ozone recovery is estimated not as natural, supposedly "free" and "gratuitous", but as the technogenic methods.

It is common knowledge that ozone is produced by passing air or oxygen through an ozonizer. The main factor contributing to the cost of the ozone production is electricity consumption. The best industrial ozonizers consume about 10 kWh of energy to produce 1 kg of ozone [3]. With an average world cost of electricity of about 0.1 USD/kWh, the cost of electricity consumed to obtain 1 ton of ozone will be approximately 1,000 USD. In fact, these costs will be significantly higher considering the cost of equipment and the overhead costs.

Thus, in order to restore the ozone destroyed at each launch of a heavy rocket, in the amount of more than 10 million tons, only the electric energy to be spent will cost 10 billion USD. Even if each rocket puts 100 tons of cargo into the orbit (there are currently no such launch vehicles on the market), the environmental damage of at least 100 million USD will be incurred per 1 ton of payload. Consequently, the minimum environmental tax on development of the near-Earth space using the launch vehicles should be at least 100 million USD for each tonne of output cargo. And no prospective reduction in the cost of launching rockets can reduce the cost of moving a ton of cargo into the orbit below 100 million USD: the harm that will be even more sensible in the future, which rockets bring to our common home – the planet's biosphere.

No less important is the location of the future extraterrestrial industry. It should be as close as possible to the consumer, i.e. to the surface of the planet, where billions of people will live. Since the industry will include a huge number of components (factories, technological platforms, power plants, residential modules, etc.), the orbits of their movement should not intersect. Otherwise, given the very high cosmic movement speeds, a destructive chain reaction of the entire system (the "domino principle") may occur, which will cause death of thousands, if not millions, of people serving the space industry. Avoidance of such a catastrophe, which probability is not equal to zero, even with the most advanced control system, can only be reached by locating the space industry in the equatorial plane of the planet.

In case of such location of the circular orbits, the velocity vectors of the cosmic bodies being at an arbitrary time on the same vertical are parallel to each other, regardless of the height of the orbit. In this case, the difference in absolute speeds of movement in the neighboring orbits is the smaller, the closer they are to each other. Therefore, here we can talk not about the possibility of collisions of the vehicles, for example, in case of emergency, but about their contacting each other. It will also make it quite easy to move from orbit to orbit and exchange the raw materials, materials, energy and products produced in the space between the neighboring orbits.

Thus, the principle of exploration of the near-Earth space in the future in the equatorial plane (Figure 1) differs significantly from the today's space exploration (Figure 2), where the orbits of the artificial Earth satellites and orbital stations are arbitrary and intersect each other[2].

We are located on the planet in a gravitational potential well, from which we can get out, either by rising to the infinity, or by flying out of it with the first cosmic velocity equal to 7,919 m/s, and not vertically up, but going to a circular orbit. Therefore, for each ton of cargo delivered into the orbit, it is necessary to bring at least 8.7 thousand kWh of energy. If you use the electrical energy generated by a thermal power plant, it will be equivalent to consumption of about 2.2 tons of fuel.

Due to this reason, the geocosmic transport is very energy intensive and should have an efficiency as close as possible to 100 % in order to avoid the global environmental problems. For example, a rocket carrier spends 20 times more fuel than it is required by the laws of physics, since almost all of its energy is not supplied not to the cargo, but is emitted into the atmosphere. And taking into account the pre-flight (obtaining the fuel components, their cooling to cryogenic temperatures, etc.) and flight costs, as well as the energy losses (the aerodynamic resistance, loss of lower stages and fairings, which manufacture consumes a huge amount of energy, etc.), the overall energy efficiency of the launch vehicle is significantly worse than that of a steam locomotive: about 1 %.

When the cargo returns from the space to the Earth, the space vehicle is decelerated by the atmosphere, thus all their potential and kinetic energy is released into the environment in the form of high-temperature plasma wake, burning of the heat-shielding envelope, acoustic waves, increasing the environmental damage caused during the initial geocosmic logistics, when delivering the cargo to the space.

[2] Only the extremely low "population" of the near-Earth orbits saves from the destructive collisions of spacecraft in such orbits at the present stage of development of cosmonautics. During transition to industrial space exploration, these orbits should be cleared of spacecraft and debris that pose danger to the equatorial industrial zone, which, as it develops, will turn into a disk covering the planet.

We do not know how technology will develop in the future, including the space technology, since we are not aware of the upcoming discoveries. The only thing we can state with complete confidence is that, whatever this technique may be, it will comply with the fundamental laws of Nature. Such laws, repeatedly tested in practice, will remain fair at all times. In the field of mechanics[3], they include four conservation laws, to which all other particular cases of conservation laws can be reduced: energy, momentum, angular momentum, and movement of the centroidal motion of the system.

In addition to the kinetic and potential energies to the space cargo, you must also bring the momentum[4] and the angular momentum (for rotation in orbit around the planet). Since the near-Earth space industry should be created from the planet, according to the conservation laws, both excess energy (equal to 100 % minus the efficiency of geocosmic transport), and the reverse impulse (like the recoil from a gun when fired), and the angular momentum (like the moment transmitted on the helicopter case from a rotating screw) should be transmitted to the planet. A rocket, for example, transmits this all to the planet not directly, but through an "intermediary" represented by the atmosphere, throwing combustion products into it at a speed of about 4,000 m/s and with a temperature of about 4,000 °C in its most vulnerable part: in the ozone layer and in the ionosphere. This causes turbulence, atmospheric and ionospheric vortices, and each time a rocket is launched, it leads to formation of ozone and ionospheric holes equal to the size of the territory of France.

Many flaws of the rocket are caused not only by the ultra-high temperatures and jet flow rate, but also by the required ultra-high engine power, about 1 million kW per ton of cargo. Imagine, for example, how much would a regular passenger car with an engine not with a power of 100 kW, but 1 million kW cost? Both the power of jet engines and acceleration (30–50 m/s^2 and more) could be significantly reduced to 1–1,5 m/s^2 which is acceptable for an ordinary passenger, as well as in the traditional land transport, if it were possible to increase their effective operation period from 4–6 min to 120–150 min. However, this unfortunately cannot be done, because according to the laws of physics, the jet thrust would decrease (with a decrease in the intensity of fuel burning), which during the flight should always exceed the starting weight, thus all rocket fuel would burn and the rocket would stand on the starting table without even moving.

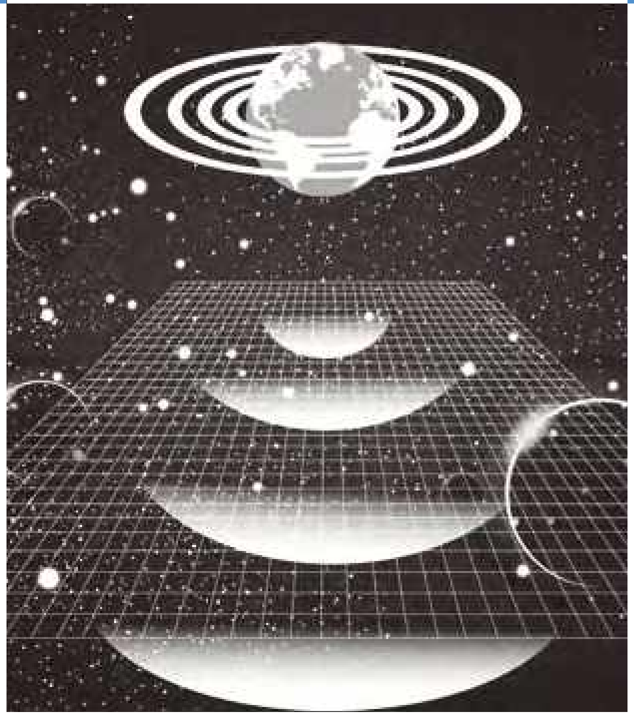


Figure 1 – Space exploration in the future

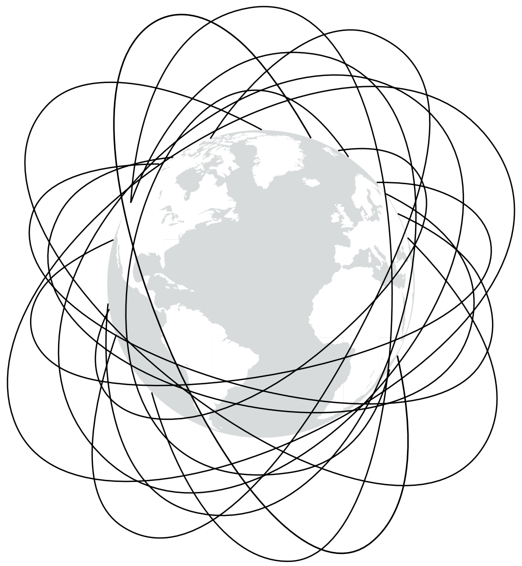


Figure 2 – Space exploration nowadays

[3] The factories, power plants, residential modules, communications and other components of the space industry to be placed on the orbit are mechanical systems with a total mass of millions of tons, so the principles of their creation and operation should be considered primarily from the standpoint of mechanics.

[4] The space cargo has the speed of movement 10 times higher than, for example, a sniper rifle bullet. This means that its kinetic energy will be 100 times higher, and the impulse will be 10 times bigger for a body of the same mass.

Thus, the basic conditions and requirements for space industrialization and geocosmic transport are as follows:

1) the space industry should be placed in low circular orbits of the equatorial plane;

2) the GCT should be designed not as a fixed structure, but as an aircraft;

3) the GCT should be as environmental friendly, self-supporting (the principle of "Baron Munchausen"[5]), working only on the internal forces of the system, without any mechanical and energy interaction with the environment in the process of geocosmic transportation;

4) the theoretical efficiency of GCT should be close to 100 %;

5) ensuring cargo flows to the extent of the millions, and in future, the billions of tons of cargo per year;

6) the possibility to recover the (potential and kinetic) excess energy of the space products during its delivery from space to Earth;

7) the use of clean energy to enter space; electric energy;

8) the GCT in the process of geocosmic transportation should transmit momentum, angular momentum and energy directly to the solid Earth's crust, without including the planet's atmosphere in the mechanical chain;

9) the power of the GCT engine in terms of 1 ton of cargo should be relatively low: not more than 100 kW, as in a passenger electric car;

10) acceleration boost for passengers and cargo should be comfortable and should not exceed 1.5 m/s^2, for which purpose the time to go into orbit and obtain the first space velocity should be at least 2 hours.

All the above 10 basic requirements are met by only one engineering solution, which is the General Planetary Vehicle (GPV), which is a self-supporting aircraft (Figures 3, 4), covering the planet in the equatorial plane. [4].

The peculiarity of the GPV operation is that the spacewalk is carried out by increasing the diameter of its ring (by 1.57 % when lifting every 100 km) and reaching at the calculated height (with passengers and cargo) the peripheral velocity of the body equal to the first space velocity. At the same time, the position of the center of mass of the GPV does not change in the process of going into space, it always coincides with the center of mass of the planet. Therefore, the regular movement (rising to a height and receiving the first space velocity at a given height) can be carried out only by the internal forces of the system, without any significant interaction with the environment.

The optimal internal driving force for GPV is the excessive centrifugal force from a belt flywheel accelerated in a vacuum channel using a linear motor and a magnetic cushion to speeds exceeding the first space velocity up to 10–12 km/s, depending on the ratio of the linear masses of the body and flywheel. This is not a very high speed: it is thousands times lower, for example, than the speed approaching 300,000 km/s obtained on the same principles in the modern charged particles accelerators.

For transfer of the momentum and angular momentum to the body of the GPV when entering the orbit in order to obtain an orbital velocity equal to the first space velocity at a given height, a second belt flywheel is needed. Then, when braking the first belt flywheel, its excess kinetic energy, since the linear electric motor will be operating in the generator mode, will not be possible to discharge it into the environment, but to recover for acceleration in the opposite direction of the second flywheel. When a double pulse is received (from acceleration of one and braking of the other flywheel), the maximum efficiency and maximum overall efficiency of the GPV will be achieved when rising to the orbit and when the body (with passengers and cargo) receives a peripheral speed equal to the first space velocity.

Thus, from the standpoint of physics, the most environmentally friendly geocosmic aircraft, using only its internal forces to enter space, has only one variant:

1) three ring structures covering the planet in the equatorial plane with the center of mass coinciding with the center of mass of the Earth;

2) ring structures have the ability to rotate around the planet and relative to each other with speeds exceeding the first space velocity;

3) ring structures have the ability to lengthen with the increasing diameter in the process of going into orbit;

4) ring structures have linear actuators along their length, capable of accelerating and braking them relative to each other.

Thus, the GPV is a reusable geocosmic transport complex for non-rocket development of the near space. The GPV will allow putting into the orbit within one flight about 10 million tons

[5] This refers to the story told by Baron Munchhausen about how he lifted himself and the horse out of the swamp, pulling on the pigtail, i.e. he used only the internal forces of the "Baron-Horse" system.

Figure 3 – Planetary vehicle combined with SkyWay transport system (*visualization*)

of cargo (250 kg per 1 m of the GPV body length) and 10 million passengers (250 people per 1 km of the body length), which will be involved in creation and operation of the near-Earth space industry. Within one year, the GPV will be able to go into space up to 100 times. It will take the modern world rocket and space industry, in which trillions of dollars have already been invested, about a million years to achieve what a GPV can do within one year. At the same time, the cost of delivering each ton of payload to the orbit will be thousands times lower than that of the modern launch vehicles – less than 1,000 USD/t.

The environment friendly GPV operating exclusively on electric energy will allow realizing industrialization of the near space. To do this, it will be necessary to close all the industrial production that is harmful to the Earth's biosphere on the planet, creating them again in the near-Earth orbit on new principles that are environmentally friendly for the space. This step will open access to fundamentally new industrial technologies through the use of unique space capabilities not available on the Earth: weightlessness, high vacuum, ultra-low and ultra-high temperatures, inexhaustible sources of energy and resources, including mineral and spatial ones. Big opportunities are opening up in the field of information and energy communications.

Bringing the industry out of the planet will radically improve our common living environment, our common home

Figure 4 – GPV construction (option):
belt flywheels 1.1 and 1.2, placed in vacuum channels;
drive systems 2.1 and 2.2, located inside the body 3;
external compartments of the capsule 4:
passenger 4.1 and cargo 4.2 (*visualization*)

(the biosphere of the planet Earth), especially in the industrialized regions, without any restrictions on production growth.

Almost all engineering solutions used in the project are widely known, tested in practice and are currently implemented in the industry. The project budget will be about 2.5 trillion USD. This is not that much, given that the annual military budget of the United States today is almost 700 billion USD. At the same time, the technological base for construction of the launch flyover will be the SkyWay systems, which will make it possible to make profit from the project at the initial stages of its implementation by transporting passengers and cargo on the surface of the planet.

Humanity has all the opportunities for implementation of the most ambitious project in the entire history of civilization. For example, about 100 million tons of metal (today, the same amount of steel is smelted on the planet in less than three weeks) and about 10 million m^3 of reinforced concrete (approximately the same amount of concrete is laid in a single dam of the Sayano-Shushenskaya HPP). Implementation of the GPV project into the world power grid means about 100 million kW (2.5 kW per linear meter of length, or 10 kW per 1 ton of cargo), which is less than 2 % of the installed net power of power plants in the world and is equal to the power of one launch vehicle capable to lift into the space less than 100 tons with one flight (and not 10 million tons of cargo like the GPV).

The linear city with millions of workplaces, built along the GPV flyover, including across the oceans, with such SkyWay transport and infrastructure complexes as urban (up to 150 km/h), high-speed (up to 500 km/h) and hyper-speed (up to 1,250 km/h), will allow the commercialization of the SpaceWay program to begin even before the terrestrial industry is put into space.

String roads today are able to earn money, people can build residence and develop business around them, the new environment friendly transport will make life even more attractive in the area of transport accessibility. The string transport and infrastructure complexes will give an impulse to the development of the previously undeveloped lands. Thanks to the SkyWay flyovers, the lines of modern information communications, electricity, water supply and fertile soil, and later on the space production will reach the most remote corners of the planet. Life will appear around them and the deserts will gradually disappear from the surface of the planet. Accommodation in the mountains and on the sea shelf will be more prestigious than, for example, the one in New York or Paris. The Human and Nature will finally be in harmony with each other.

Besides this, the research and development work on the GPV will be carried out, which will require about 5 % of the total project investment. Generally, it will take at least a couple of decades to solve all the engineering problems. Despite the fact that the work has been going on for many decades [5], the implementation of this large-scale project is hardly possible only using the efforts of the team created by the engineer and author of the GPV, A. Unitsky more than 30 years ago.

We believe that such global geocosmic program with common goals and objectives will unite all countries of the world, will attract them to finance this super-ambitious project, designed to save the humanity. Due to its technical features, the project will directly affect the territory of dozens of countries (mainly located along the equator), and due to the political and economic reasons – the whole world. The GPV and the industrial necklace around the Earth will become an indispensable platform for advanced exploration of the deep space by reusable space vehicles, and a security circuit to prevent the space threats, including the meteoritic ones. The project implementation period will take about 20 years, taking into account the socio-political, research, development, design, survey, construction and installation works.

The world around us was created by the engineers. Not the bankers, not the politicians, not the artists, but the engineers. However, this world is often ruled by those other people, for whom personal enrichment is at the forefront; those who naively believe that in the situation where the planet will be on the verge of destruction, money will be able to save them. They are sure that they and their families will be able to find shelter on their personal islands, in underground bunkers, on submarines and "Boeings" with antimissile defense system. How wrong they are! The planet is a one big room that does not even have partitions. Many centuries ago the primitive people and their leaders burned fires in their caves and died of lung cancer at the age of 20. They were able to survive only due to the fact that they had guessed to move their primitive technologies (ordinary fire) beyond their home. So now we, the terrestrial civilization, should bring the technosphere outside of our home (the biosphere). All engineering solutions for this step, ensuring transition of humanity to a new stage of civilizational development, have already been created.

There is no doubt that during implementation of the General Planetary Vehicle project it will be necessary to cope with a large number of problems and difficulties both in a technical and social way. However, they are insignificant in comparison with the problems to be settled by our earth's civilization, if it is going to survive and develop.

Ideas which changed the world in the past have always seemed fantastic and unreal to their contemporaries, but with the efforts of the engineers they took real embodiment. Science has given us the tools to make the world a better place, but we don't want to use it because of our inflexibility and conservatism. Is it possible today that continuing to build millions of kilometers of roads and considering a rocket the only "key" to the space, we are ready to move to the Mars at the price of a one-way ticket amounting to one billion dollars and die there? I do not want to believe it. If this is not true and we want to live, then we need to have the courage to change ourselves, each of us!

We did not inherit the Earth from our ancestors, we borrowed it from our descendants. We have to work out this duty, otherwise we will not have any future for everyone: the earth's technocratic civilization will disappear as a failed experiment of the Universe.

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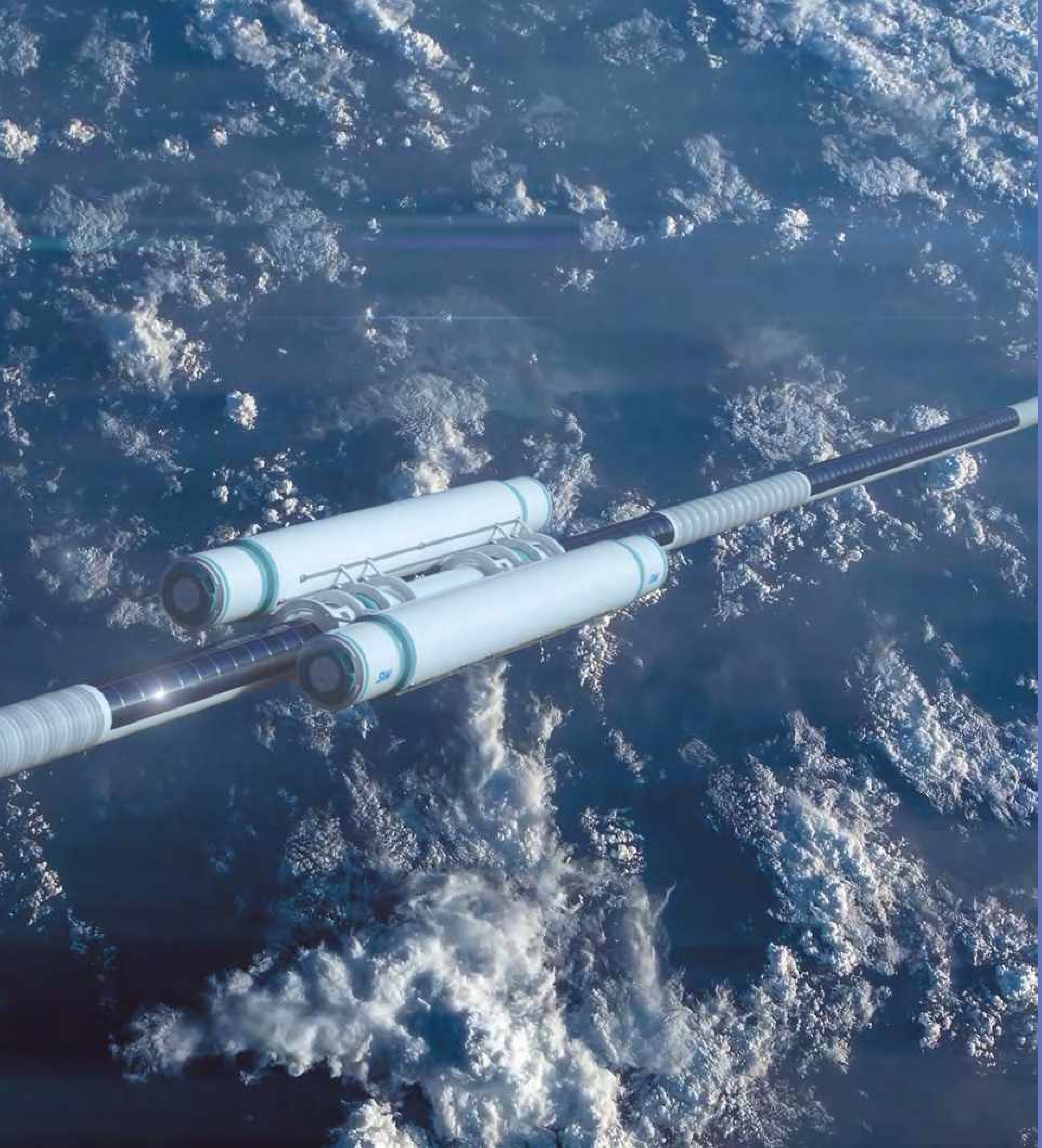


UDC 629.78

Description of the structural elements of the SpaceWay astroengineering transport system

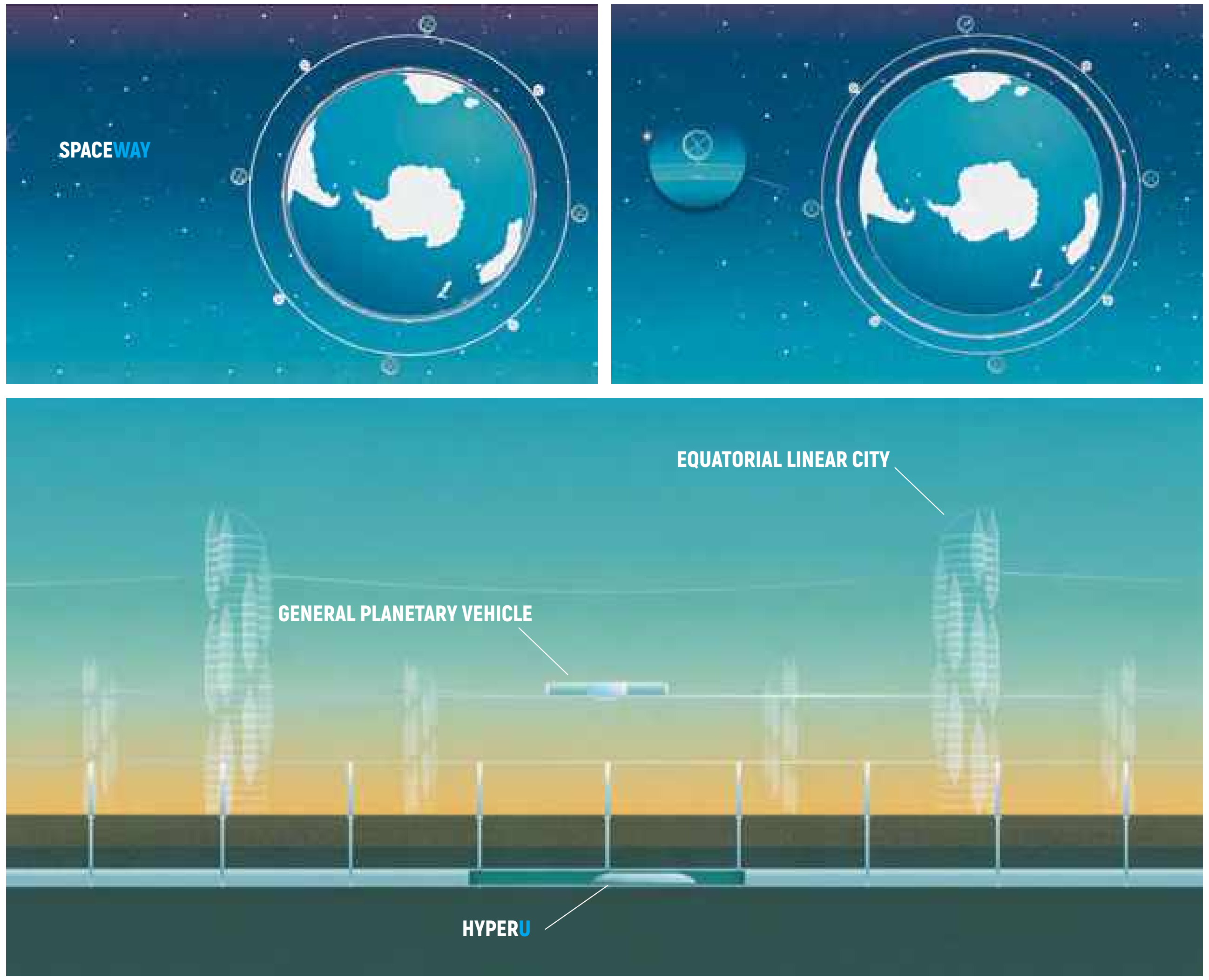
A. UNITSKY (Minsk)

Video visualization frames showing the process of the General Planetary Vehicle (GPV) launch from the starting flyover with subsequent exit to the low near-Earth orbit. The living and production modules of the Industrial Space Necklace "Orbit" (ISN "Orbit") are demonstrated as integral parts of the SpaceWay astroengineering transport system.

SpaceWay – is a comprehensive non-rocket space industrialization program. Its main goal is to move the environmentally harmful industry from Earth to Earth orbit for the sake of preserving and restoring the ecology of the Blue Planet.

The SpaceWay program implementation includes three main components:

1) Equatorial Linear City (ELC);
2) General Planetary Vehicle (GPV);
3) SpaceIndustry.

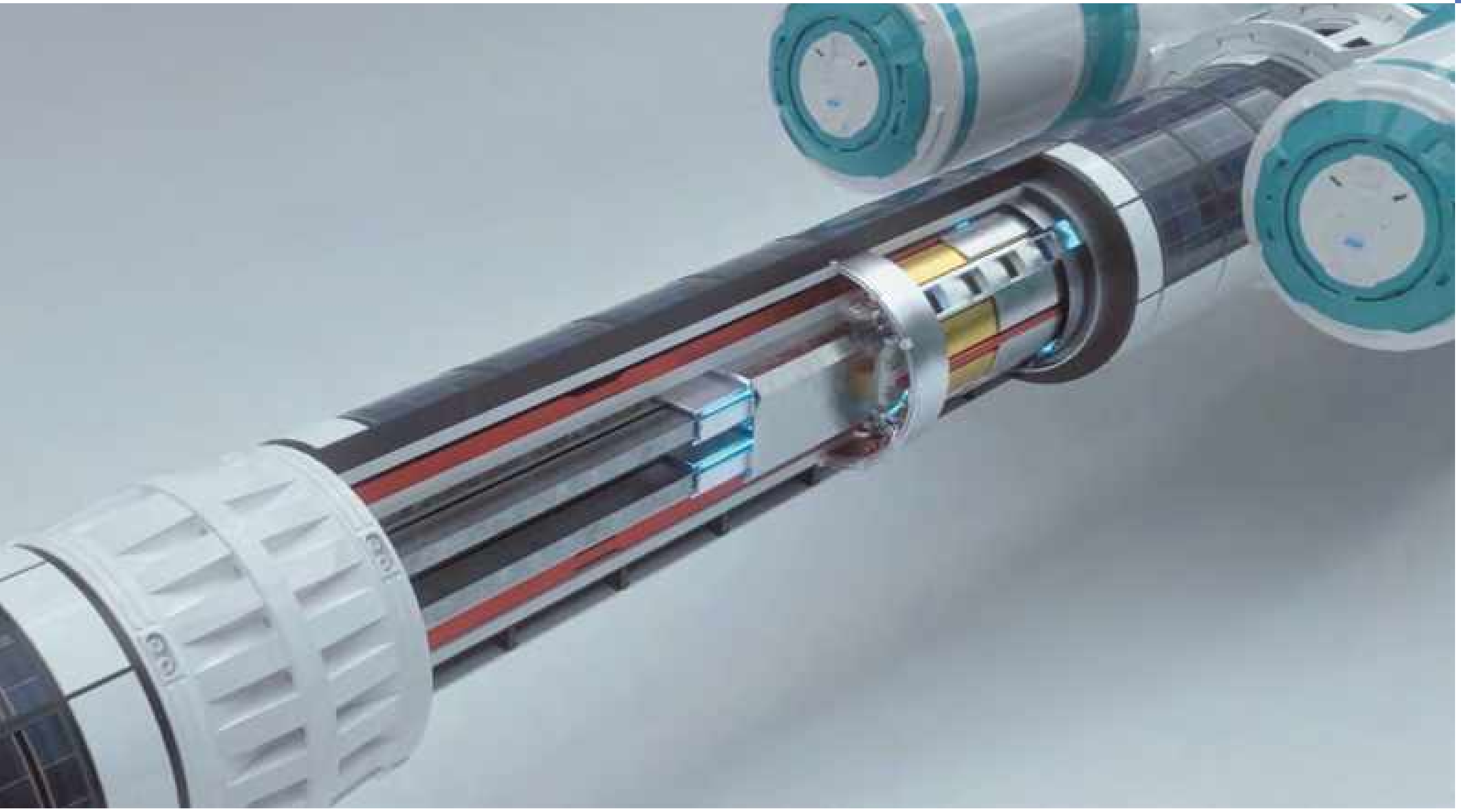


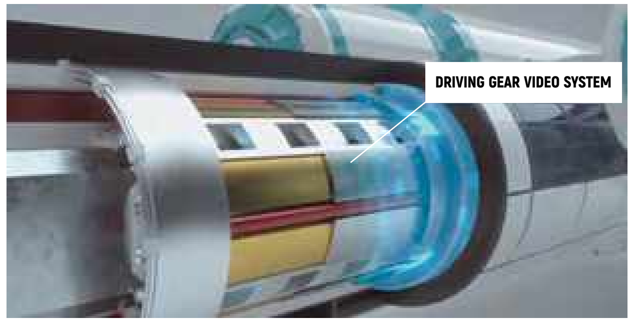
The Equatorial Linear City (ELC) is an extensive network of residential and industrial clusters united by transport and energy communications necessary for the distribution of cargo delivered to the orbit and back. The central axis of the city, along which the GPV take-off and landing flyover is laid, should be in the equatorial plane in land and sea sections. Passenger transportation and cargo delivery within this network is provided by SkyWay high-speed ground transport, as well as HyperU hyper-speed transport, in which the rolling stock moves in a forevacuum tube, which allows eliminating air resistance and speeding up to 1,250 km/h.

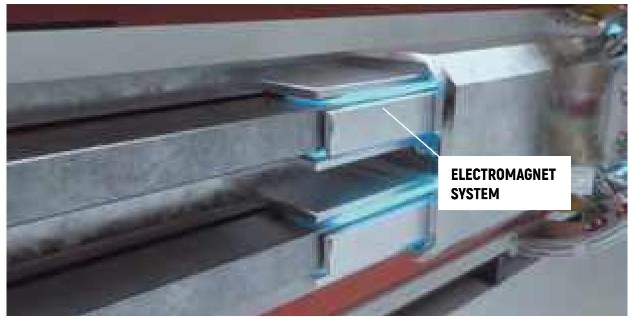
The General Planetary Vehicle (GPV) is a reusable self-supporting aircraft operating in the Earth - Orbit loop. The structure encircles the Earth in the equatorial plane, and the takeoff is carried out from the flyover, also serving as a landing platform. The system is driven by the centrifugal force resulting from acceleration of the flywheels of a linear electric motor located in its core. Cargo and passengers are accommodated in special modules attached to the GPV hull and distributed along its length using SkyWay and HyperU high-speed transport. Per each flight, GPV is capable of transporting 10 million tons of cargo and 10 million passengers for the construction and maintenance of the space industry.

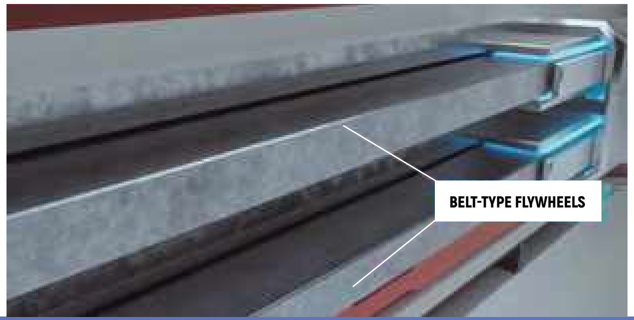
Despite the impressive size of the GPV structure, the price of a passenger ticket to the Earth orbit will be about 100 USD, while the level of comfort during space travel will be higher than when traveling on Earth. Low prices will be achieved not only due to the low operating costs of GPV, but also due to the one-time transportation of a huge number of passengers and a large amount of cargo.

Like a stretched thread having infinitely small transverse dimensions with respect to its length (1 : 10,000,000 ratio), GPV acquires the property of a stable self-supporting structure.









The GPV hull is a solid vacuumized tube with an electric motor elongated in a continuous line and belt flywheels inside it. All these individual elements are placed in advance inside the hull, connected to each other, and then air is pumped out of the tube, and vacuum is created.

In order to lift the GPV into space, it is necessary to accelerate the belt flywheels in the linear motor hull to a speed exceeding the Earth orbital velocity.

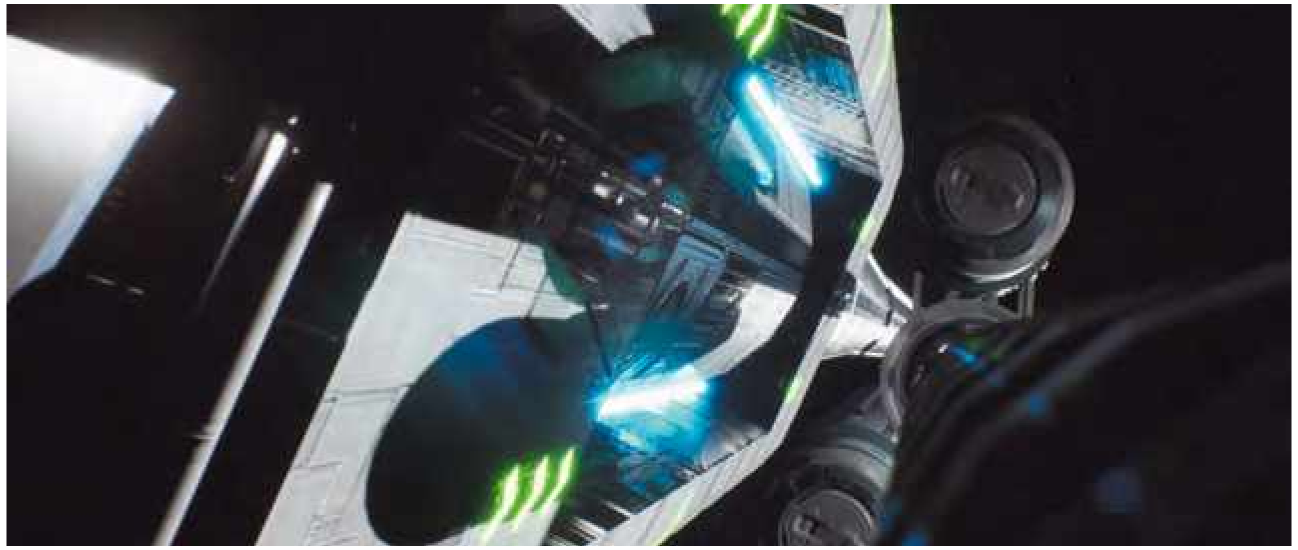
As soon as the electromagnets are turned on, the flywheel belts start to levitate between them in the vacuum, without experiencing environmental resistance. Due to the connection to external power sources, the flywheel belts are set in motion, rotating around an axis passing through the Earth mass centre. As speed increases, the flywheels accumulate the necessary amount of kinetic energy, which allows lifting the GPV in the air and take it out into space.

After the flywheel belt has reached the calculated speed, it becomes weightless. With a further increase in the flywheel speed, the centrifugal force acting vertically from the centre of the Earth exceeds the weight of the flywheel, providing excess lift. As a result, the GPV hull with all the cargo and passengers begins its ascent to a defined orbit.

Due to the fact that rotor rotation creates centrifugal force exceeding the earth gravity, the GPV hull breaks away from the launching flyover. As it moves from the Earth's surface into space, the GPV hull begins to expand evenly.

In order to ensure the constant balance of the hull, GPV, if necessary, is supplied with a special ballast system.

As ballast, environmentally friendly substances such as, for example, water and oxygen will be used. If sprayed in the upper atmosphere, they will help restore the ozone layer of the Earth and will allow managing the weather and climate on the planet safely and environmentally.



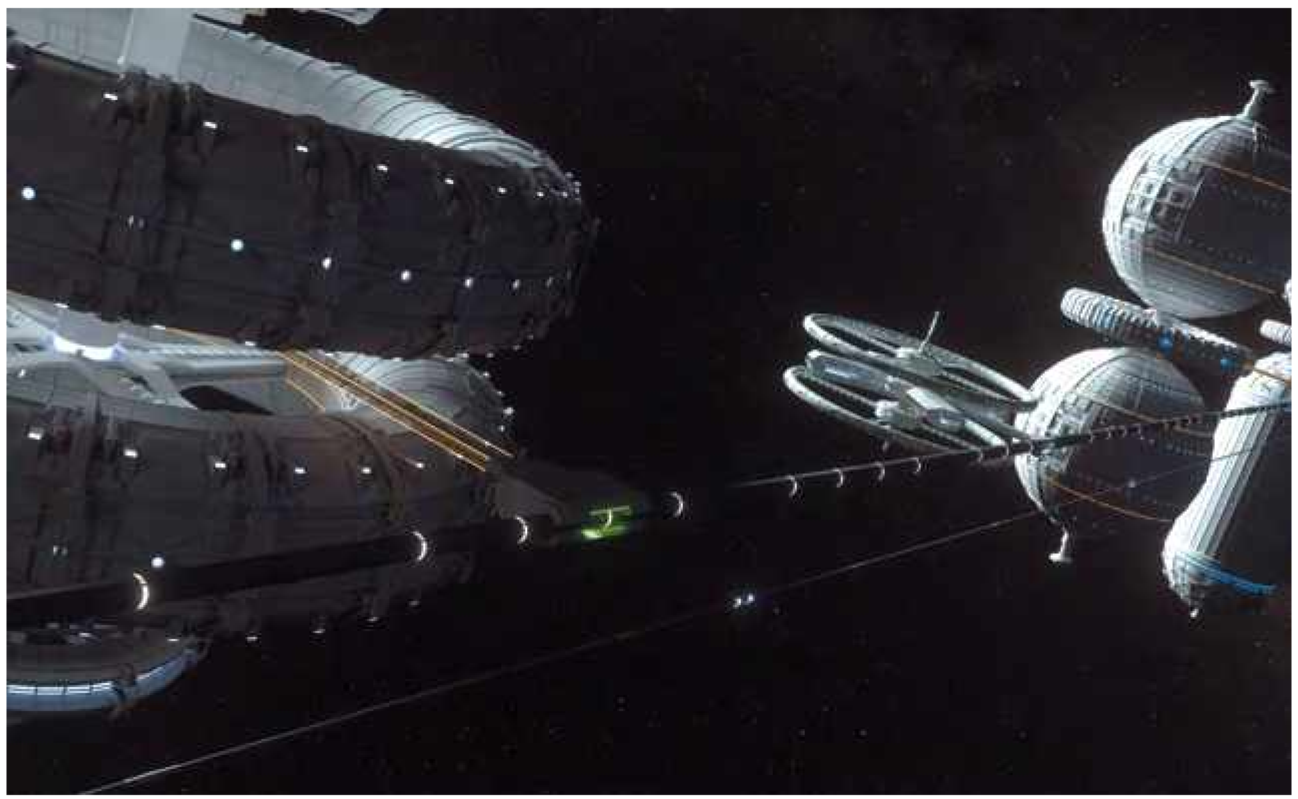
SpaceIndustry is a network of industrial and residential facilities located in the equatorial plane in low circular orbits. Space plants, factories, power plants will be located here, as well as residential space settlements – EcoCosmoHouse (ECH), where the staff serving the space industry will live and work.

After the target orbit is reached, GPV will unload cargo and passengers into the complex that surrounds the entire planet along its entire length.

The industrial space necklace elements are interconnected by transport, energy and information communications, and with the planet Earth, by means of GPV geocosmic aircraft.

The constructional part of residential facilities is a sphere, a cylinder or a torus as the most optimal alternatives. All of them rotate around their axis, creating artificial gravity.

Inside the carrier shell of a residential cluster made of high-strength materials, living quarters have been set up, there is also a layer of soil and there is a similar to the Earth's atmosphere. Outside and inside the structure is equipped with meteoroid and radiation protection.



EcoCosmoHouse (ECH) is a space structure with an autonomous biosphere. Each ECH has artificial gravity and regulated habitat parameters. The ECH's biosphere can provide autonomous living for up to 10,000 people.

Passenger and cargo modules of GPV can be used not only for transportation, but also as a full-fledged housing.

Such residential modules may constitute a separate zone of the EcoCosmoHouse. Together they will form a kind of low-rise dwelling suburban areas, where each family has its own space.

The modern level of science and technology development allows implementing the SpaceWay program in the foreseeable future. This will require significant investments, as well as efforts from researchers and inventors. However, the resources expended will be more than replenished, since the program opens for humanity access to the unlimited energy, spatial and raw material resources of space. In addition, SpaceWay will allow us to gradually get rid of harmful industrial enterprises on Earth, due to which its ecology will be restored and conditions will be provided for a comfortable and safe life for humans in harmony with nature.

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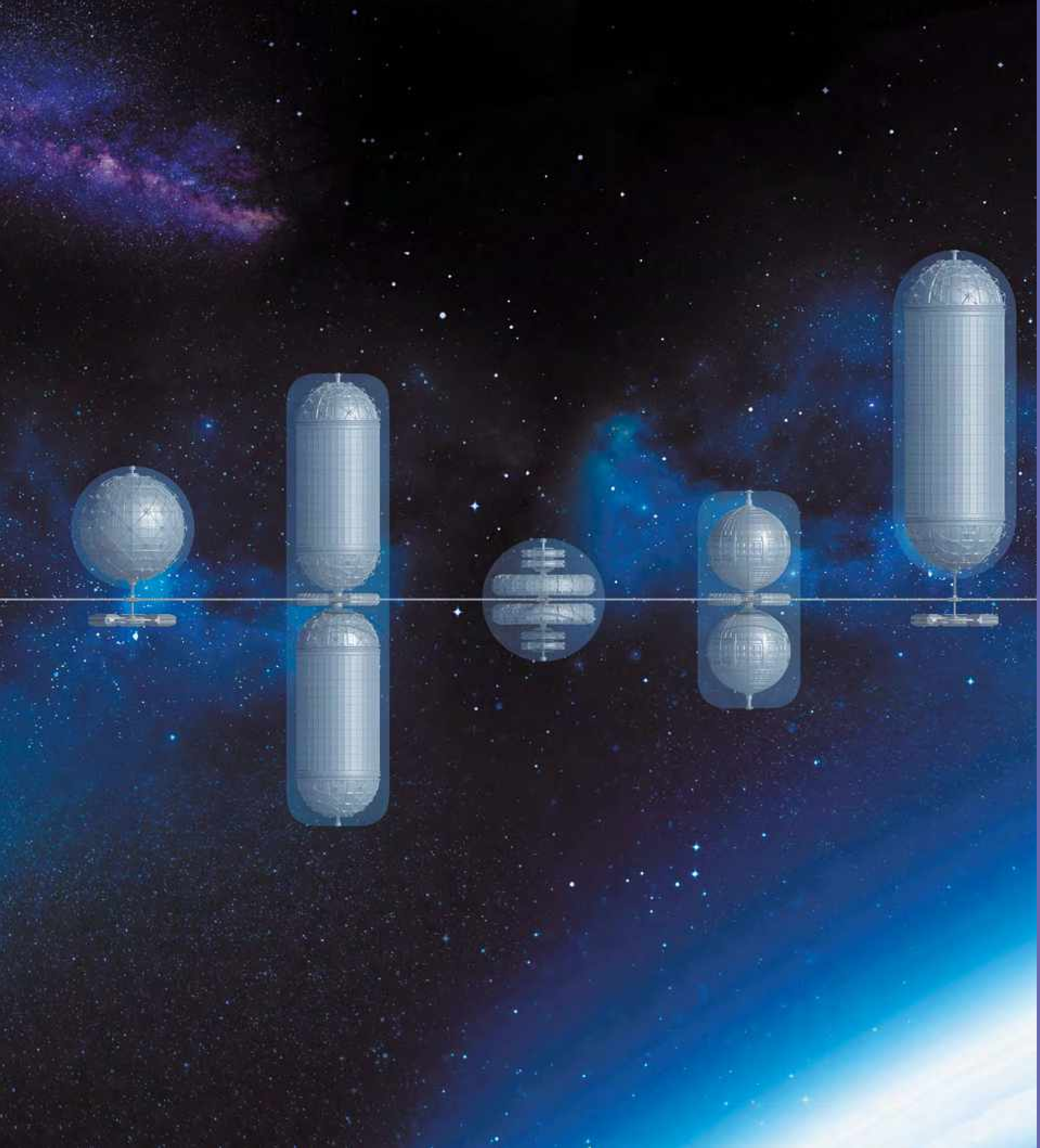

UDC 629.786

Features of design of a residential space cluster "EcoCosmoHouse" – mission, goals, purpose

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The article contains the comprehensive study of a residential space cluster "EcoCosmoHouse" (ECH) not only as an integral part of the orbital transport and infrastructural, industrial and residential complex "Orbit", but also a growth zone around which the space industry will be crystallized. The possibility of creation in these multifunctional clusters of the conditions for human existence, which are different from those present on Earth: gravitation, atmosphere and living environment, is described in the paper. The special attention has been given to modelling of Earth's biosphere, including all its elements, inside of ECH: flora, fauna, including microflora and microfauna. The paper describes the design of the space residential cluster, as well as estimated costs and approximate of volume of materials needed to construct a cluster in orbit. Moreover, the paper contains the comparison of the levels of living comfort, cost of the building, usage and maintenance of EcoCosmoHouse with these of settlements existing today on near-Earth orbit, of the type of International Space Station (ISS).

Keywords:
EcoCosmoHouse (ECH), complete ecological system, biogeocenosis, living fertile soil, immune system, space industrialization, General Planetary Vehicle (GPV).

During industrialization of the near space first of all the Industrial Space Necklace "Orbit" (ISN "Orbit") – an orbital transport and infrastructure, as well as industrial-residential complex covering the planet in the equatorial plane and having an appropriate length of 42,567 km (for height of 400 km), should be created. The construction of the ISN "Orbit" will begin from the first launch of the General Planetary Vehicle (GPV) [1].

The industry created in the space for the benefits of the Earth civilization, in spite of the automation and robotization should also be serviced by people, although in the limited quantity in comparison with technologies on Earth. In Earth industry, including transport, energetics, communication and information technology work now about billion specialists. Maybe in the future the manpower needs will reduce by 1,000 times to 1 million specialists. The number of the tourists and rest travellers will be approximately the same, as it is possible to create in space the recreational complexes with better conditions then on Earth. In the view of the above it would be necessary to create new types of residential space settlements – EcoCosmoHouses (ECH) in which will live, work, have rest, take therapy and undergo treatment millions of people (Figure 1).

In ECH for some thousands people – in small social community, of a village, built using innovational principles – will be recreated the best part of the terrestrial biosphere with all necessary conditions: atmosphere, variety of landscapes, living organisms, soils, biogeocenosis, water ecosystems and excite will be created the most comfortable physical conditions: gravitation: gravitation (using centrifugal force), illumination in the natural spectrum, optimal temperature, pressure, air humidity and etc.

The transverse size of these structures is up to 500 m, so as not to increase their sail spread, which impede the entire industrial complex due to the presence of a gas medium at this altitude although very rare (one can speak about the atmosphere at the altitude of 400 m only conditionally, due to its very low density: 3×10^{-12} kg/m^3).

For comfortable living in space people need the conditions that are similar to these on Earth or even surpass them by quality.

Comfortable gravity. Gravity in orbit can be modelled using centrifugal forces. It is not unlikely that the most comfortable gravity would be reduced gravity similar to that existing on the Moon and Mars, with acceleration of gravity of about 2 m/s^2, i.e. five times lower than on Earth. In such

Figure 1 – The design of the part of the Industrial Space Necklace "Orbit" with double-type torus-shaped ECH (variant), to which flies the GPV with passenger (cargo) nacelles (*visualization*)

a case the weight of the adult would be about 15 kg and one could easily jump on the roof of the house and fly like a bird, he/she would have wings.

Comfortable atmosphere – by pressure, composition, humidity and temperature:

1) Pressure in the atmosphere of the space house. It is possible that in orbit will be comfortable the pressure similar to that in the mountains on Earth, for example, two times lower than atmospheric pressure, that is, 0.5 kgf/cm^2, or 5 t/m^2. Reducing the pressure two times will reduce the load on the body of the space house, due to the pressure of the atmosphere inside and increase its reliability and operating life with significant reduction of the value;

2) Atmospheric composition. In order to avoid oxygen starvation, the oxygen content can be doubled, for example, up to 40 %, if the atmospheric pressure is reduced by half compared to that on Earth. The oxygen content should be limited to the upper value, at which self-ignition of various combustible substances (for example, wood) can occur, wish will be used in EcoCosmoHouse. The content of other gases (nitrogen, argon, neon, carbon dioxide, etc.) should also be optimized. Moreover, the house might not have any zones with stagnant air, i.e. it should be arranged the air exchange – air movement: either by means of convection or with the help of special fans, e.g. disguised as windmills;

3) Air humidity. Since the human body, as well as animals and plants, gets moisture not only from food, but also from the air, the humidity of the atmosphere in a space house must be optimal during a day and the whole year, for example, e.g. equal to 55–60 %, (if necessary it can be adjusted both during a day and during a year);

4) Air temperature. Air in a space house can have an optimum temperature throughout a year equal to +21... 25 °C (if necessary it can be adjusted both during a day and during a year in more wide range);

Duration of a day and a year. The concept of the day and year in orbit loses its meaning, as ECH will make one revolution around the planet in about 1.5 hour, i.e. 16 times during the Earth day, passing through sunrises and sunsets. Thus, a day and a year in EcoCosmoHouse can be of an optimal duration, which differ, from 24 hours and 365 days, respectively. Therefore an orbital house is to have artificial lighting and a day and a year can have optimal duration which is different from 24 hours and 365 days respectively. For example, 24-hour biorhythm is imposed and violent for most modern urban residents, as evidenced by the regular use of the alarm clock.

Illumination. The comfortable illumination is necessary not also for people living ECH, but also for plants and animals. For healthy development of the plants the light intensity should be not less than 1,000 lux. The light is to be:

- *of high quality.* A plant at each growth phase requires its own spectral composition of the light. Thus, a plant needs blueish light for development of green mass, for growth of the root system and during the preparation to flowering the spectre should have the shades of yellow and red. Greenish light beams stimulate process of photosynthesis in the leaves with dense structure;
- *continuous.* Most plants gain strength and bloom only when the daylight is not less than 14 hours, i.e. in summer. At same time there are plants which during flowering should be located under the light not more than 8–10 hours per day. Taking in account the above the illumination in ECH should be local, depending on the ecosystem;
- *intensive.* Low light is harmful for plants. The ideal variant for light-demanding plant species is 100,000 lux that is similar to sun light. In any case the source of light in a space house should be the sun, either thorough special mirrors and lens or by means of conversion of light into electrical energy.

Comfortable living space (environment) for a human. In the space house, there shall be biosphere of the planet must be fully modelled as the cradle of a man with a history of evolution numbering billions of years, including the preceding one. The flora and fauna from the favourable for human life climatic zones of Earth should be represented in all their diversity, since we are rooted to them (for example in our blood rustles an ancient ocean and the mineral composition of blood completely similar to that of the ocean water), including the microflora and the microfauna – the soil biogeocenosis with thousands species of microorganisms.

A kilogram of healthy fertile soil contains about a trillion soil microorganisms of several thousand species – they are all necessary for the existence of flora and fauna in the terrestrial biosphere, including humans. The fertile soil on the planet is the immune system of its biosphere and vital for its health. When the living fertile soil on Earth will be killed and replaced with the dead, artificial soil impregnated with herbicides and pesticides and richly fertilized with mineral fertilizers, this will be the beginning of the end of the terrestrial biosphere – the one we all know and of which we are a part. At that precisely time can easily occur a pandemic capable of killing all the people within just a few days. Two-hundred-meter yacht, Boeing with missile defence or own island in the ocean will not help anyone to survive.

It is impossible to create comfortable and safe living conditions for a human in the EcoCosmoHouse without healthy (living) fertile soil. For example, the core of the human immune system is the microflora and microfauna of its intestine, which is mostly considered to be soil microflora. There live trillions of microorganisms of thousands of species [2]. They work days and nights feed us, give us a drink and even… treat. No wonder many experts designate the contents of the guts as our second brain.

The biosphere of a space house must constantly produce the oxygen necessary for people and animals living there to breathe, to produce healthy food and to process all wastes of vital activity of living organisms in humus. The basis of the fertility of soil, including the most fertile soil on the planet – the dark rich soil is humus, insoluble salts of humic acids [3]. Figuratively speaking, they are "conserves" for plants, opened with a special "can opener" – microorganisms, living in the soil (if humus is soluble, the first rain could wash it out from the soil). The microorganisms process humus into a soluble form and feed and give a drink to the plants establishing with them a kind of symbiotic relationship. No plants can exist without such a symbiosis but with mushrooms, since mushrooms not only live in the plants themselves, but also form a mushroom root with their roots, which feeds and water their host and is a network for information exchange for them.

On Figure 2 are shown residential and natural zone of torus-shaped ECH, on Figure 3 – residential apartments. In the space zones with high meteoroid threat, living apartments and offices can be created in nacelles of GPV, by which passengers and cargo will be delivered in orbit. These nacelles are hermetically sealed, has their own life support system, sustain overpressure and have a hatch (access door). Therefore, even in the event of a depressurization of a space house caused by hit of large meteorite, residents can escape by closing hatch and fasten its closed.

Figure 2 – Living (left) and natural (right) zones of torus-shaped ECH (*visualization*)

Figure 3 – Residential apartments of ECH (variants) created in the nacelles of GPV (*visualization*)

Protection against meteorites and radiation. The existing orbital stations do not fully protect from meteor and radiation hazard that exists in space, and in the near-Earth orbit. For example, a drop of water at a speed of 20 km/s can penetrate tank armour, and cosmic radiation can kill a person in a few days, since its level is much higher than at the emergency Chernobyl nuclear power plant. Not heavy-duty thin-walled screens, but thick multilayered barriers can be most effective from both of these dangers. They may include foams, and a many meters layer of fertile soil inside the space ecohouse, as well as water and air.

Composite elements of EcoCosmoHouse. The most optimal option of the structural part of the space-housing cluster is a hollow sphere or cylinder or torus (Figure 4) or their combination with a diameter of 200–500 m) spun around its axis. For the beginning it would be enough to have massive space settlements, which can be created as paired, located in line or near each other, or placed inside each other as in nesting girl (Matryoshka). This allows getting any rotational speed using electrical, but not jet engine. One cover will rotate in one side and the other – in the opposite direction.

Bearing body of the space house is made of high strength materials and is the most non-material-consuming part of such a house. For example, if it is made of composite materials produced by industry today, the thickness of the bearing wall of such a huge structure will be just 3 mm. The most most material-intensive part of the spherical house will be anti-meteoritic and anti-radiation protection, as well as a layer of fertile soil – their total thickness will be up to several meters.

The inner surface of the sphere will be layered with the living fertile soil and forests, gardens, meadows planted with their biogeocenoses. There are ponds with fresh and seawater including their ecosystems.

The inclined part of soil approaching the axis of rotation contains mountain landscapes, with streams and waterfalls and its submontane ecosystems. The air in the space house is filled with the smell of flowers and useful phytoncides, which favourable action on the human body cannot be compared with any medicines. There is no noise except for the singing of birds and the whisper of the leaves of trees.

Figure 4 – The Industrial Space Necklace "Orbit" (ISN "Orbit") with torus-shaped EcoCosmoHouse (*visualization*)

The approximate weight of materials needed to build a space house in orbit for 5,000 people will be approximately 400 thous. tons, including:

- structural shell – 2,000 tons;
- anti-radiation and anti-meteorite protection – 100 thous. tons;
- fertile living soil (eco-black earth) – 200 thous. tons;
- water (fresh and sea) – 100 thous. tons;
- air – 10 thous. tons;
- building materials and structures, including for apartments inside the space house – 50 thous. tons;
- other – 38 thous. tons.

The delivery of all materials into orbit for one EcoSpaceHouse with the help of GVP will cost about 500 million USD (about 1,000 USD/t). The materials and substances for it will cost approximately the same amount – 500 million USD, installation work in orbit will cost about 1 billion USD. Thus, space settlements to host up to 5,000 people for living and working will cost about 2 billion USD, which is almost 75 times cheaper than the International Space Station*. The costs of which exceeded 150 billion USD [4].

Therefore, the money the humanity has spent today for up to a dozen astronauts to have the possibility of being in orbit (in very uncomfortable and life-threatening conditions) will help (using GPV) to build 75 space settlements for 375 thous. inhabitants who will live and work in much more comfortable conditions than on Earth.

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UDC 327.7

Socio-political framework of SpaceWay program implementation

E. PETROV (Minsk)

The article discusses relevance of the SpaceWay program within the framework of achieving the goals of sustainable development, the possibilities and prospects of representing the SpaceWay project at the United Nations Organization, and some regulatory and legal aspects of the issue. The analysis of international cooperation experience in implementation of large-scale infrastructure projects has been completed.

Keywords:
SpaceWay, General Planetary Vehicle (GPV), sustainable development goals.

In the 70s of the XXth century, A. Unitsky, the engineer and author of the SpaceWay project, started substantiating the need of space industrialization. His idea implies that the environmental problems are an expected result of the technocratic civilization development, which created an industry on Earth that entered into relationship of irresolvable antagonism with the planet's biosphere. "There is only one principal way out of this situation," writes A. Unitsky, "it is necessary to provide the technosphere with an ecological niche outside the biosphere. This will ensure the preservation and development of the biosphere in accordance with the laws and trends that formed during a billion years of evolution, as well as the balanced interaction of the community of people (as biological objects) with the biosphere. There is no such an ecological niche for the technosphere on the planet Earth. But there is one in the space, where there are ideal conditions for the most technological processes: weightlessness, deep vacuum, ultrahigh and cryogenic temperatures, unlimited raw materials, energy and spatial resources, etc. Thus, we conclude that there is a need of space industrialization, if the earth civilization continues the technological path of development in the future" [1]. This idea was a prerequisite for inventing the SpaceWay program, aimed at creating the technological basis for the large-scale exploration of the outer space by mankind. The General Planetary Vehicle (GPV) developed by A. Unitsky should become such a basis.

"GPV is a reusable geocosmic transport system for non-rocket space exploration. Within one flight, GPV will allow putting into orbit about 10 million tons of cargo and 10 million people, who will be involved in creation and operation of the near-earth space industry. During one year, GPV will be able to go into space 100 times. Modern world rocket and space industry, in which trillions of dollars have already been invested, will need about a million years to repeat the same which GPV could make within one year. At the same time, the cost of delivering each ton of payload to the orbit will be ten thousand times lower than that of the modern launch vehicles." [1].

Having obtained the opportunity to bring harmful production out of the biosphere thanks to invention of GPV, the mankind will be able to ensure the necessary conditions for improving the ecological, economic and social environment for the long term, as the main cause of environmental pollution - the industry - will be located outside. GPV will allow forming a new wide niche in the production, scientific and technical activities, to open access to new raw materials and spatial resources, etc. Implementation of the SpaceWay program involves interaction at the international level. In this regard, along with the scientific, technical and economic aspects, there arises a question of socio-political framework, which could unite the subjects of the program.

In modern dictionaries and encyclopedias, the concept of "community" is synonymous with the concept of "society" and has the following meanings: 1) a number of people united by historically determined social forms of relationship and activity; 2) a circle of people united by common position, origin, interests; 3) a voluntary, permanent association of people for any purpose; 4) organization, union of people setting common tasks for themselves. The concept of "politics" (in Greek "politika" is the art of governing the state) is interpreted as the activity of state authorities and public administration expressing the socio-economic nature of the given society, and the activities of classes, parties, groups, determined by their interests and goals [2].

Therefore, the socio-political basis may be regarded as the central element of the value system, which acts as a regulator for the activities of the government bodies and associations of people represented thereby, pursuing any common goals. Consequently, the search for the socio-political basis for implementation of the SpaceWay program should proceed from its goals, the main one of which today is undoubtedly the preservation and improvement of the ecological situation on the planet. This priority is in direct correlation with the priorities identified by the United Nations as the goals of sustainable development, adopted by 193 UN member states on September 25, 2015.

"The goals in the field of sustainable development are a kind of a call to action, coming from all kinds of countries: poor, rich and moderately developed ones. It aims at improving the well-being and protection of our planet. The states recognize that the measures to eliminate poverty should be taken in parallel with the efforts to increase the economic growth and address a range of issues in education, health, social protection and employment, as well as to combat climate change and protect the environment" [3].

The UN documents define 17 global goals.

1. End poverty in all its forms everywhere.
2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
3. Ensure healthy lives and promote well-being for all at all ages.
4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
5. Achieve gender equality and empower all women and girls.

6. Ensure availability and sustainable management of water and sanitation for all.
7. Ensure access to affordable, reliable, sustainable and modern energy for all.
8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
10. Reduce inequality within and among countries.
11. Make cities and human settlements inclusive, safe, resilient and sustainable.
12. Ensure sustainable consumption and production patterns.

13. Take urgent action to combat climate change and its impacts.

14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

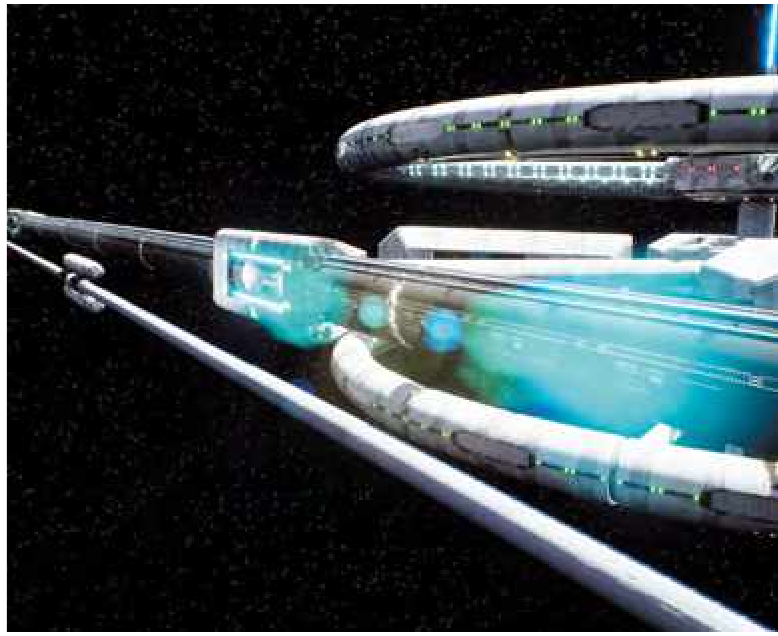
16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development [3, 4].

Implementation of the SpaceWay program may be a decisive factor in achieving all of the listed goals. It involves creation of many additional jobs, including in a number of the least developed countries [5] along the equator line, where the GPV starting flyover will be built, combined with Equatorial Linear City (ELC).

The program will provide access to the new low-cost energy sources, create conditions for economic growth, become the basis for creation of inclusive infrastructure. The culture of consumption and production, the harm from which for the environment should gradually be reduced to a minimum, will shift to a completely different quality level. The ecological potential of the project is enormous. The vast majority of problems associated with environmental pollution, climate change, preservation of forests, oceans and biological diversity, desertification and land degradation can be solved. Thus, the global potential of the SpaceWay program and its compliance with the priorities of the international development, as recorded in the UN documents, leave no doubt. Therefore, the UN may be considered one of the components of the socio-political basis of the program implementation process at the initial stages, and may also act as a tool for implementation of a number of important functions in the context of the program.

As already mentioned, the GPV starting flyover should be built along the equator line, passing through the territories of several countries. However, the biggest part of it will be laid through the ocean, which will require a large number of approvals at the international level. It may be necessary to introduce amendments or additions to the international regulatory documents: for example, the UN Convention on the Sea Law or the Treaty on the Principles of States Activities in the Exploration and Use of the Outer Space, including the Moon and other celestial bodies. To this end, it seems necessary to create a non-profit organization to represent the SpaceWay project at the UN, which might later enter its structure or act independently as a lobbyist, providing the necessary interaction between other structural units within the UN and the member states, and also being an intermediary in the context of cooperation with the scientific institutions, industrial and commercial companies involved in implementation of the SpaceWay project.



The most likely form of funding and working on the SpaceWay program today is considered the public-private partnership. This mechanism was previously successfully used in a number of large international infrastructure and scientific projects, for example, such as Eurotunnel and the International Space Station (ISS). The latter is nowadays the most expensive international scientific project: since its launch in 1998, more than $150 billion has been spent on assembly and maintenance of the ISS. Hundreds of companies, state structures of the USA, Russia, Canada, Japan, Italy, member states of the European Space Agency and Brazil took part in the work [6]. It is obvious that the number of participants in the SpaceWay program will be no less, and the costs according to preliminary estimates will reach about $2.5 trillion. However, taking into account the fact that already within the first year of the GPV operation the economic effect from the program implementation may amount to $1,000 trillion [1] and it will increase in the future, the attraction of the international community to participate in the program in the foreseeable future is already an achievable task, in case of systematic development of its scientific, technical, economic, socio-political and other components. Since the sustainable development goals proclaimed by the UN coincide with the SpaceWay goals, and since the UN has a certain political influence at the international level, it is reasonable to consider the United Nations as one of the key components of the socio-political basis for implementation of the SpaceWay program.

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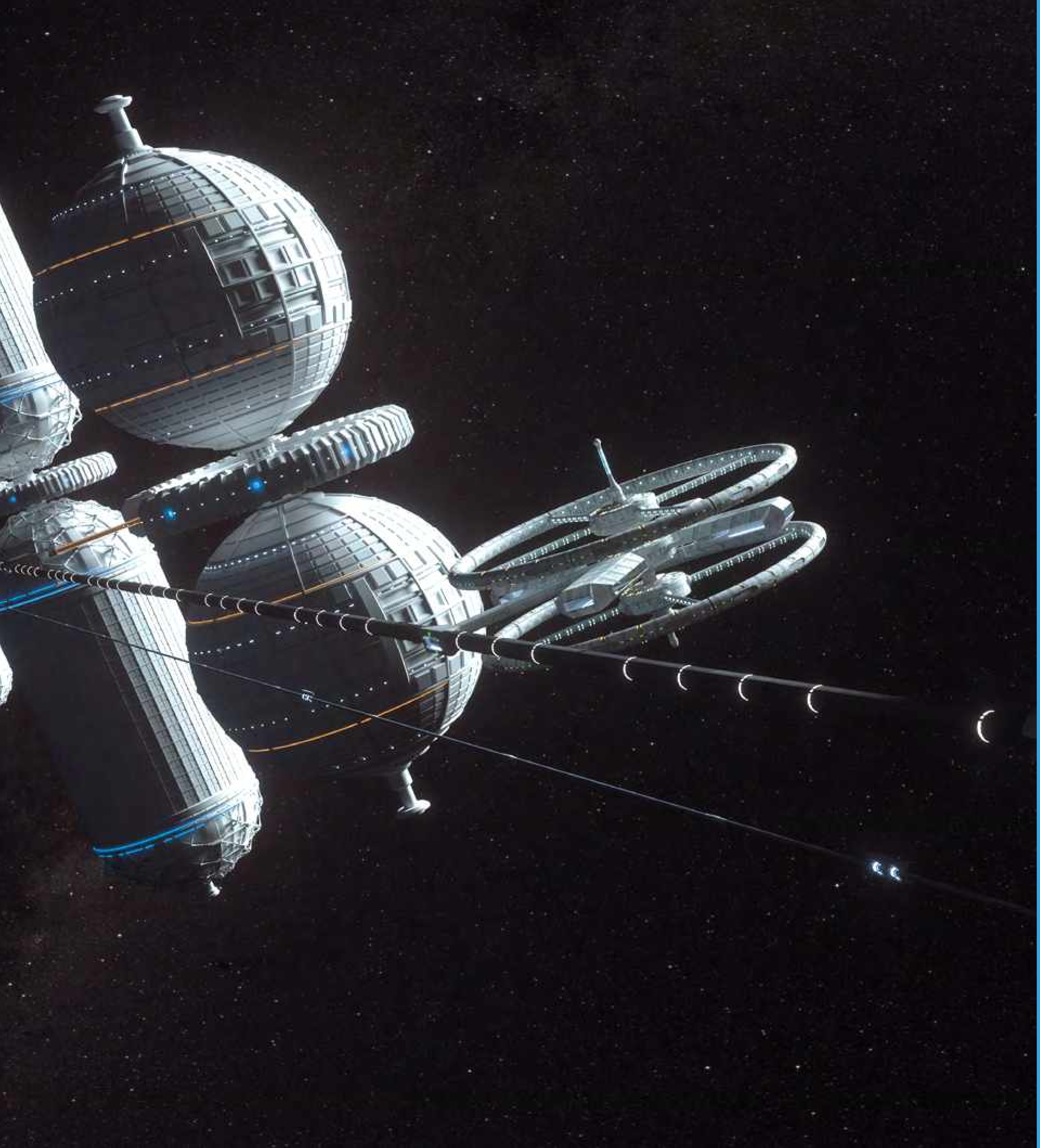

UDC 629.78

Space industrialization megaprojects: rocket, space elevator, StarTram, General Planetary Vehicle

A. UNITSKY (Minsk), I. NADEEV (Saint-Petersburg)

Considerations to the main actual industrialization methods of circumterrestrial orbits and their comparative characteristics are given and described by the following parameters: ideal technology efficiency, impact on planetary ecology, effective payload, cost of low earth orbit (LEO) injections, annual output, specific turnover per earthian. Conclusions to the necessary requirements and criteria for optimal method of near-Earth space environment industrialization (technologically, environmentally and financially) as well as geocosmic transport (GCT) based thereupon.

Keywords:
General Planetary Vehicle (GPV), space elevator (SE), StarTram, non-rocket space industrialization, space cannon, inflatable elevator, rocket.

Over the past 60 years from the beginning of humankind space activities the powerful success have been achieved in exploration and use of space to develop science, solve defense, economic and environmental issues. During this period, we passed a milestone of space exploration development as a full-featured sphere of society activities, affecting not only national but also global economies. At the same time, a number of problems and contradictions have accumulated due to the lag of the space industry during the transition to a new design form based on efficient and environmentally friendly technologies. We came up to the next boundary, a kind of milestone on the way to space. Now is the time to summarize and assess the prospects for development of astronautics, its impact on Earth civilization for purposes of survival and development of the human race.

This milestone involves selection of a new cosmonautics development strategy, initializing practical implementation of superglobal space development projects based on environmentally friendly technologies – relevant or advanced to environmental standards that do not adversely affect the environment, human life and health as well as offer the properties of rational consumption of natural resources [1]. Each of these megaprojects is designed to ensure the security and development of humankind on and out of the Earth, develop extraterrestrial resources and objects, create orbital and extraterrestrial colonies as well as space civilization.

When choosing a strategy for space development, it is important to be on the safe side not only with regard to the tools – technologies forming the basis of a mega-project – but also to selection of priorities, i.e. development of circumterrestrial orbits, the Moon or Mars. Each of the global megaprojects (outside of the Earth, the social space of the human race and planetary connections) requires checking for environmental friendliness and technical consistency: mega-projects vary from large cannons (including nuclear ones) to laser launch, from electromagnetic catapult ramps to space elevator. Comprehensive scientific assessment of all known and future geocosmic transport systems for development of near-Earth space environment was given more than 20 years ago in the works of engineer A. Unitsky [2], that showed but not limited to lack of prospects for rocket-powered vector of space industrialization, large-scale exploration of the Moon and Mars.

The purpose of this article is to study possible ways of large-scale exploration of circumterrestrial orbits, assess the capabilities of their implementation today and the prospects of their application in the future. The costs associated with these megaprojects are artificially high, and vehicle launch costs may not include state-subsidized launching infrastructure, so this work does not include any direct cost comparisons. The methodological basis consists of scientific studies on this issue of domestic and foreign scientists.

Let us start the survey with the only "space baggage" available for humankind today – **launch vehicle:** for the past 60 years the impelling power in cosmonautics is presented by only thermochemical reaction propulsion engines that are the most primitive on the scale of traction space systems [3].

Launches of Russian "Proton" vehicles from Baikonur site cause ionospheric turbulence over the territory of the Altai Mountains as well as reduction in vertical component of the geomagnetic field. As a consequence, galactic cosmic rays and high-energy electrons from the Earth's radiation belt penetrate with the atmosphere. When interacting with a dense atmosphere, they generate X-rays that can penetrate even closer to the surface of the Earth. Considering that not only ozone holes, but "ionospheric" ones occur in case of launch of the space vehicles, the rocket route by its definition serves as a passage for penetration of highest-energy particles to the Earth's surface with a strong negative impact on living organisms.

The rocket method of circumterrestrial orbit development inflicts great harm on planetary ecology: livestock falls – four-footed beasts are poisoned by grass, on which the combustion products of rocket fuel settle down. For the same reason the vegetation perishes; acid rains destroy the flora and fauna of the planet while falling along the course line of space vehicles. Also the vehicle launches affect the planetary climate: the ozonosphere is destroyed by fuel combustion products of rocket engines at heights of 15 to 50 km. This atmosphere slice protects all flesh on Earth against solar UV emission, therefore, the increase in the number of skin cancer cases is associated with loss of ozone layer. In addition, "Proton" uses highly toxic and mutagenic heptyl (650 tons) as fuel that four times more toxic than, for example, hydrocyanic acid. One fuel loading of "Proton" is enough to poison all current humanity, all 7.7 billion people.

Following the launch of launch vehicle, a wave of cyclonic activity increases and atmospheric pressure drops violently near the earth's surface by 10–15 mm Hg upon the average. Moreover, the consequences are recorded in the vast territories including millions of square kilometers. As a result, each time these effects generate at least two additional powerful atmospheric cyclones. Each missile launch creates a passage with a low electron concentration in the planet's ionosphere. The "random" launch function, their various power and geographical location of missile platforms (total number of launches for the years of space exploration has exceeded 5,800) create waveways to transfer seismic energy into the ionosphere and space and solar streams into the earth's crust. This whole complex of negative influences brings us to the point of no return, when the planet's biosphere will be impossible to be recovered [4].

Among other things, the global problem is created by waste products of up-to-date cosmonautics activities – space rubbish acting not only as reflector of partial sun light, but contributes to additional warming of upper atmosphere parts when heated. In fact, the Earth's waste sphere with a number of large (more than 10 cm), medium (1 cm to 10 cm) and small (1 mm to 1 cm) fragments was created using the rockets during the last 60 years of the space age, respectively: 34 thous., 900 thous. and 128 million pieces [5]. Even small a centimeter fragment is able to drill a hole in a tank armor half a meter thick at a speed of 8 km/s, without mentioning of thin lining of any type of space vehicles that can collide in orbit (this applies to any megaproject considered in the article). Therefore, all this rubbish constitute a serious danger for future space industry. Today there are more than 10 thous. tons of rubbish accumulated in orbits

200–5,500 km high that amounts to more than 1 % of gross gas mass inside the high-level atmosphere. This problem requires an early solution, otherwise it will lead to a dead end in the future space industrialization.

On the other hand, missile technologies have reached the top of their technological state of the art, while the rocket cosmonautics never became widely available for total consumption, to be used in the national economy of the Earth. It can be concluded that launch vehicles are not suitable for space industrialization – too expensive to operate and harmful to the environment. In view of this, there is a need to consider other ways of space industrialization.

Space elevator (SE) is a heavy-duty self-supporting cable, expanding upwards 100,000 km long (for space station version as a counterweight), one end is fixed on the surface of the Earth, and the other end is on geostationary orbit over the counterweight (Figure 1). A space station or asteroid can be used as a counterweight to provide constant tension of the cable [6]. Cargoes are lifted to orbit by a "mountain climber" – a special elevator which at most will be on route for 11 days (one way).

At first glance, this megaproject attracts with relative simplicity and ease of execution, however the problems lie in details.

1. An elevator cable is technically a very long and flexible "clothesline", the transverse load on which is created not by the weight of the linen, but by the Coriolis force from the moving elevator car.

When building a simulation model of space elevator considering it to the cable bending capability and design

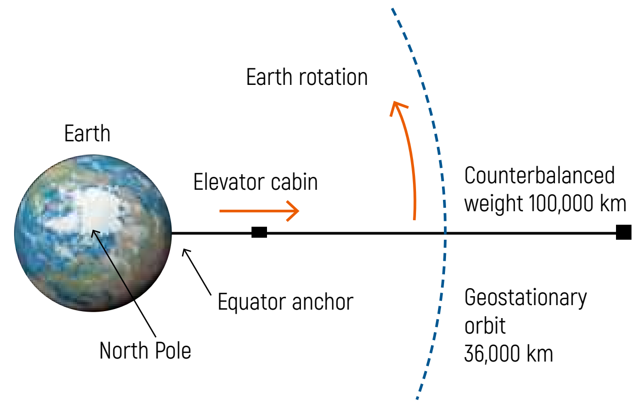

Figure 1 – Diagram of space elevator

features of elevator mechanism (Figure 2), cable oscillations with ever increasing amplitudes (Figures 3–4 [7] show the corresponding relationship graphs of angles α_1 и α_2 and times), resulting in space elevator swinging – not just from the movement of elevator itself, but also with increase in weight of the lifted load, become apparent. These phenomena are caused by effect of Coriolis force (and Coriolis inertial force, which grows in proportion to the load weight), which tends to deflect the cable from the local vertical. It is worth noting that cargo weight for space elevator has an upper limit – its increase shifts the mass center of elevator to the Earth. Provided that the distance between the mass centers of Earth and elevator becomes less than the critical value, the elevator will simply fall to Earth [8]. Based on these limitations, the annual capacity of the space elevator cannot be high – it is estimated to be no more than 5,000 tons/year, that is the same order as of launch vehicles.

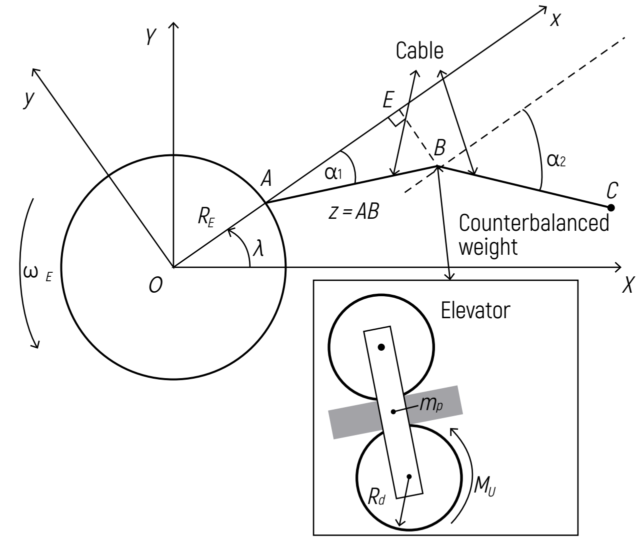

Figure 2 – Mechanical space elevator system

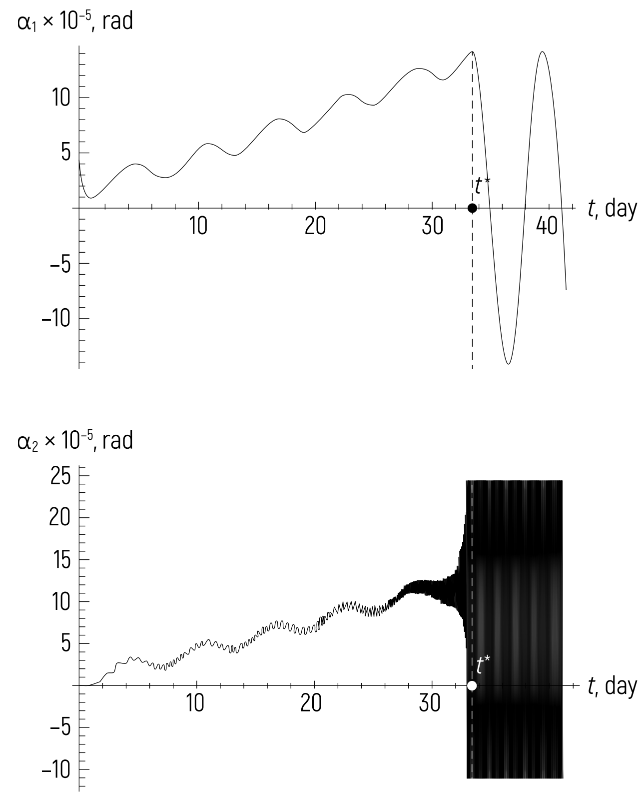

Figure 3 – Graph of angular oscillation α_1 and α_2

2. Since the elevator speed can be high that even at a speed of 100 m/s (360 km/h), one-way trip will take more

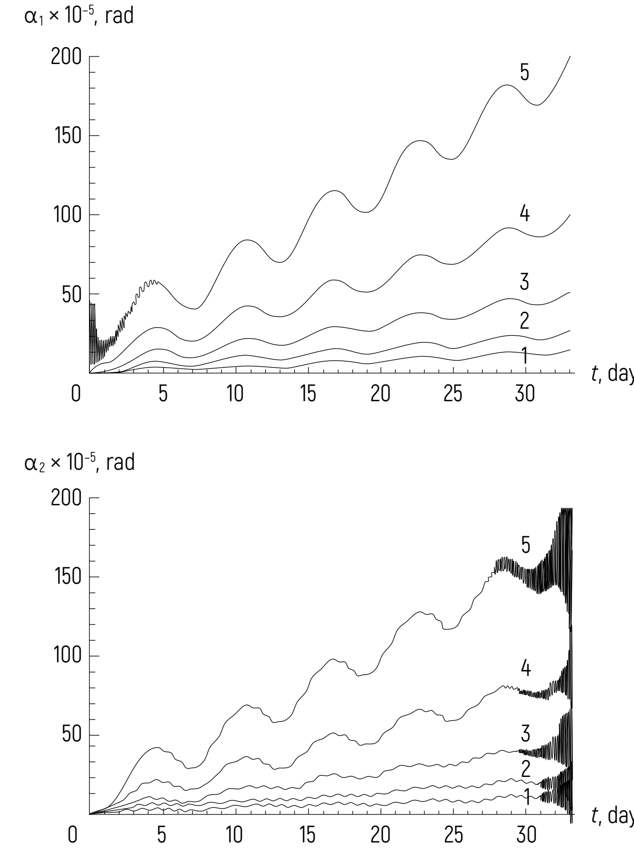

Figure 4 – Graph of α_1 and α_2 coordinate variation for various cargo weights

than 11 days, that dramatically reduces the attractiveness of this type of geocosmic transport (GCT) for passenger transportation – during this period a person will receive lethal radiation dose while passing through Van Allen fields [9]. Besides, cosmic radiation can also lead to deterioration of structural elevator elements, defect occurrence and even breakage of rope.

3. Since tractive force of the elevator should exceed its weight, it will require to input power exceeding 10 MW, similar to high-speed train, at a speed of 100 m/s to move up a small 10-ton module. It is reasonable easy to supply electricity on the Earth, including laying of a high-voltage power transmission line along the route, mounting large-volume step-down substations every 20–30 km and supplying all the way with a contact network. However, in case of space elevator, all these electric communications with gross mass of hundreds of thousands tons will hang on load cable, adding extra complexity to structural elements and task to construct facility that may exceed in length the extent of Russian railway system.

4. By definition, SE is a single-track railway of extremely low efficiency – figuratively speaking, you should wait for the last car coming from the surface of the planet to deliver space products back to the Earth.

5. Power transmission to 10 MW along the elevator by wire at a distance of tens of thousands of kilometers will result in huge energy losses. For this reason, it would be more rational to use wireless means of energy transmission or use local means of energy production to feed SE. For example, using solar irradiation or nuclear power industry, but there is no ready-made solution for SE at the moment.

6. Since the circumferential speed of cargo, delivered into space, corresponds to the first cosmic velocity only in one orbit – geosynchronous (height 35,786 km) with orbital velocity 3.07 km/s (first cosmic velocity at this height), this cargo cannot be delivered to lower orbits – it will fall back on the planet or will move to the elliptical orbits with low perigee.

7. Space elevator, which mass will amount to million tons, should be constructed not from Earth to space, but from space to Earth, therefore, rocket missiles are required. By the most conservative estimate space delivery of elevator construction materials only will cost in the amount of more than 10 trillion USD. At the same time, the construction period can last for thousands of years (based on the total carrying capacity of rocket missiles launched in 2018 – 1,082 tons) [10, 11, 12].

8. Superstrength material for the cable is not invented yet – even carbon nanotubes considered to be the most durable material at the moment are not suitable.

Conclusion. The concept of space elevator does not withstand reasonable criticism by criteria of functionality, performance, construction period, structural reliability and cost.

The inflatable elevator to send space vehicles (SV) and spacecrafts into outer space is offered by Thoth Technology, a Canadian company (Figure 5) [13]. Thoth Tower 20 km high (230 m wide) is a prototype of a space cannon and consists of reinforced inflatable sections with internal elevator. The main purpose of the tower is to launch SV from its upper part (thus, the tower replaces the first stage of launch vehicle, reducing its costs by one third), as well as for landing and refueling.

To ensure the dynamic stability of the structure from wind load, it is supposed to use a flywheel system that will act as compressors for the structure: they will be able

Figure 5 – Diagram of Thoth Technology inflatable elevator

to regulate pressure and rotation, compensate any tower bending and will continually keep it in a fixed state.

The main disadvantage of inflatable elevator is that it is an active structure and therefore it requires a constant power supply, otherwise the construction, in full compliance with physical laws, will fall down on Earth (while not immediately, but in a few hours later without energy consumption). Notwithstanding that all the materials and technologies, required to construct this megaproject are available, it essentially acts as an inflatable crutch for modern astronautics being lame in both legs: it seems to be, but it is impossible to lean on.

The space cannon, sometimes called Jules Verne's gun (due to its appearance in the novel From Earth to the Moon), is a method to launch an object into outer space using a large gun or cannon design [14]. This method does not have the best characteristics.

1. While passing dense atmosphere, the hyper speed of the projectile (appr. 10 km/s) will lead to formation of powerful impact waves, significant energy losses and intense projectile burning (therefore, it should take off with higher speed than the first cosmic velocity).

2. Short shank. The projectile will accelerate for about 2 s with acceleration of appr. 5,000 m/s^2 (500 g), even with barrel length of 10 km, therefore, not every cargo will withstand such overload (Figure 6) [15]. In this case, the power of such cannon should amount to appr. 50 million kW per ton of cargo delivered into outer space.

3. Cargo movement vector on firing does not correspond to any circular orbit. Therefore, the projectile movement should be adjusted using a reaction propulsion engine, otherwise the projectile will fall back on Earth or will fly away into outer space (in case of delivery at speeds exceeding second cosmic velocity).

As we can see, this method not only affects adversely the atmosphere (in acoustical, chemical and thermal aspects), but most of cargo is simply may burn away due to aerodynamic heating or will be broken by aerodynamic resistance. Besides, this method is not suitable for creation of a spacemen – human organisms are not adapted to overload of 500 g.

The StarTram, as several very similar concepts (electromagnetic catapult, orbital cannon) are based on launching the objects into outer space using electromagnetic accelerated "shot" of a huge cannon to transfer sufficient speed so that the "projectile" inflight consumes minimum fuel and bear maximum cargo.

The StarTram is a vacuum launch tube with plasma window at the end and a length of 1,500 km (for the system of generation 2, providing passenger transportation - overload of 3 g) which rises magnetically above the surface of Earth, up to a height of 22 km. The launch tube levitates due to the magnetic repulsion force that occurs between superconducting cables attached to the tube and cables attached to Earth. These forces raise the launch tube of 7 m in diameter, stabilized both vertically and horizontally because of impact of the total upward magnetic force and wind forces using anchor lines attached to Earth. Inside the launch tube, the StarTram reusable spacecraft is moving, levitating on magnets and accelerates almost to orbital speed in an vacuumized tunnel (Figure 7) [16].

Figure 6 – Diagram of waterstart space gun

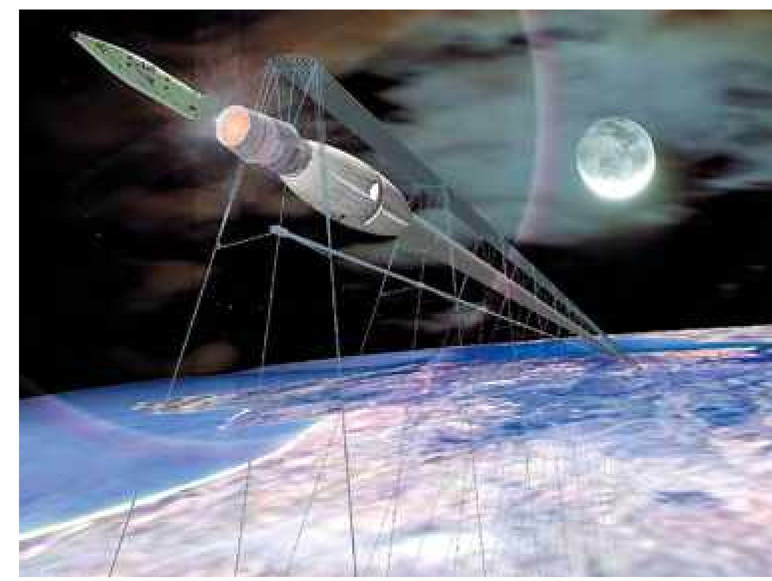

Figure 7 – Diagram of the second generation StarTram

This project has the following main disadvantages.

1. Erection complexity for the launch vacuum-treated tube, the base of which will experience significant forces caused by its own weight and wind load for the entire launch tunnel, levitated to a height of 22 km. For example, lower kilometers of the tunnel will experience compression from atmospheric pressure of 10 t/m^2, therefore it will be quite massive – similar to a superheavy train set weighing thousands of tons, which, moreover, should levitate not at a height of several centimeters from track structure, but at a height of many kilometers.

2. Air resistance in the lower atmosphere requires heat-resistant design of "projectile" shell that significantly reduce its payload. Moreover, escape of hypervelocity projectile from the vacuum-treated tube to atmosphere is practically unrealizable technologically.

3. Magnetic levitation of such object should be recreated using a power source with a monstrous current of 280 MA, plus a "weaker" current of 14 MA, which should be directed to the opposite direction along the tube surface, therefore high-temperature superconductors should be also used additionally.

Conclusion. This system provides specific annual turnover of 15 g per earthian. A passenger positioned inside the electromagnetic coil of this capacity for such a long time, can cause memory loss and death.

General Planetary Vehicle (GPV) – is a reusable geocosmic transport system for rocket-free exploration of adjacent space. GPV is capable to inject into orbit appr. 10 million tons of cargo and 10 million persons per trip. Annually, GPV will be able to go into outer space up to 100 times with unit costs of payload orbit delivery less than 1,000 USD/t (Figure 8) [17]. This is the only possible reversible GCT with two-way cargo traffic – it takes off and lands back similarly, while other geocosmic transport systems lower cargo by braking the capsule in the earth's atmosphere (except for space elevator).

To exit into space this geocosmic spacecraft uses only its own internal forces and has, based on physics, only one possible option of design style: three ring structures – a body and two belt flywheels, covering the planet in equatorial plane. Ring structures are capable to fly around the planet and relative to each other with speeds exceeding the first cosmic velocity, moreover the flywheels move in vacuum-treated channels. In addition, they can be extended with increasing diameter in the process of ascent to orbit (by 1.57 % for every 100 km of ascent), have linear actuators along their length, capable of accelerating and braking them relative to each other.

a) б)

Figure 8 – Visualization of General Planetary Vehicle:
a) during take-off from a ramp (left), b) at the time of mating to the Industrial Space Necklace "Orbit" with toroidal EcoCosmoHouses located on it (right)

No technological defects were found in this project. Among other things, it is worth mentioning its planetary scale, as a result of which it will be necessary not only to come to the negotiating table for almost all countries of the world, but also to change quite a lot of applicable international legal acts (Outer Space Treaty, Convention on the Law Of the Sea, etc.).

The most important characteristics presented in megaproject review, providing identification of main requirements to optimal GCT for the planet of Earth, are summarized in tabular form (Table).

According to the survey results, it is possible to formulate the main conclusions on the necessary requirements and criteria for optimal GCT (technologically, environmentally and financially).

1. To move to the next phase of outer space exploration the humankind is extremely in need of technologically feasible superglobal project based on eco-friendly technologies – starting point for sustainable development of our technocratic civilization that will not be able to withdraw from industrial vector of its development in the future. Successful implementation of any super-global project is possible only for transition to a new technological mode using fundamentally new, effective and environmentally friendly technologies.

2. To provide successful industrialization of space, space productions should be located in low circular orbits in the equatorial plane, but not on the Moon or Mars. GCT itself should provide annual cargo capacity of millions and billions of tons eventually – the space industry should be proportionate in scale to the earth one. Such cargo and passenger traffic without affecting biosphere of the planet, a microscopic part of which is humankind itself (the mass of all people on the planet is appr. 1/50 000 of the mass of living matter) can be provided by the system using internal forces.

3. Principles of physics (conservation of system energy, momentum, angular momentum and centroidal motion) should be observed when creating an extraterrestrial industry. GPC should work only using internal forces of the system, without any mechanical and energy interactions with environment during transportation, including mechanical interactions with planetary atmosphere and its ozone and ionosphere layer.

4. At the same time, GCT should provide not only cargo transportation, but also transportation of passengers in both directions. However, boost acceleration should be comfortable for passengers and cargo and should not exceed 1.5 m/s^2, for which time of ascent to low circular orbit should be at least 1,5–2,5 hours. It follows, that boost path under conditions

Table – Comparison of main circumterrestrial orbit industrialization methods

Circumterrestrial orbit industrialization method	Specific payload, t (pass.)	Estimated cost of injection into LEO, USD/t	Annual capacity, t	Future cargo turnover per earthian, kg/person. per year	Max. ideal technology efficiency, %	Load per person (overload), m/s^2	Technology availability level*
1. Rocket launcher	118 (6)	3,000,000	2,000	0.0003	2	90	9
2. Space elevator	18 (10)	400,000	5,000	0.0006	90	10	4
3. Inflatable elevator	40 (0)	2,300,000	15,000	0.002	90	30	2
4. Space cannon	0.45 (0)	500,000	50,000	0.007	7	5,000	6
5. StarTram	35 (0)	200,000	150,000	0.02	90	30	3
6. GPV	10,000,000 (10,000,000)	≤ 1,000	≥ 100,000,000	≥ 100	99	2	5

* 1 – basic principles; 2 – approximate concept; 3 – theoretical demonstration; 4 – laboratory tests; 5 – subsystem trials; 6 – demonstration prototype; 7 – active prototype; 8 – successful tests; 9 – successful operation.

of Earth should be significant – more than 20,000 km, that is, it should be circinal.

5. GCT engine power should be relatively low on conversion to 1 ton of cargo, appr. 100 kW that is equivalent to a relatively inexpensive light motor vehicle (try to imagine the cost of a motor vehicle with an engine power of 1,000,000 kWh/t as with outer-space rocket). At the same time, it should use for its operation the most environmentally friendly electric energy.

6. Self GPC should not be formed as a fixed structure, and as a self-supporting vehicle with the theoretical efficiency, close to 100 %, which is relatively inexpensive can be mounted on the surface of the earth rather than in outer space such as, for example, a space elevator.

Among all GCTs presented in this review, only GPV complies with all these six requirements: due to internal forces – in terms of ecology; due to infinite boost path – in terms of comfort of human ascent to orbit; due to extensive section of product line (it comes out into outer space with no relatively small transversal section, but its entire length of 40,000 km) – in terms of high volume production capability, etc. It can be exactly considered as the most advanced and efficient near-Earth space industrialization megaproject based on environmentally friendly technologies. The other methods presented in the study lead to a space dead end.

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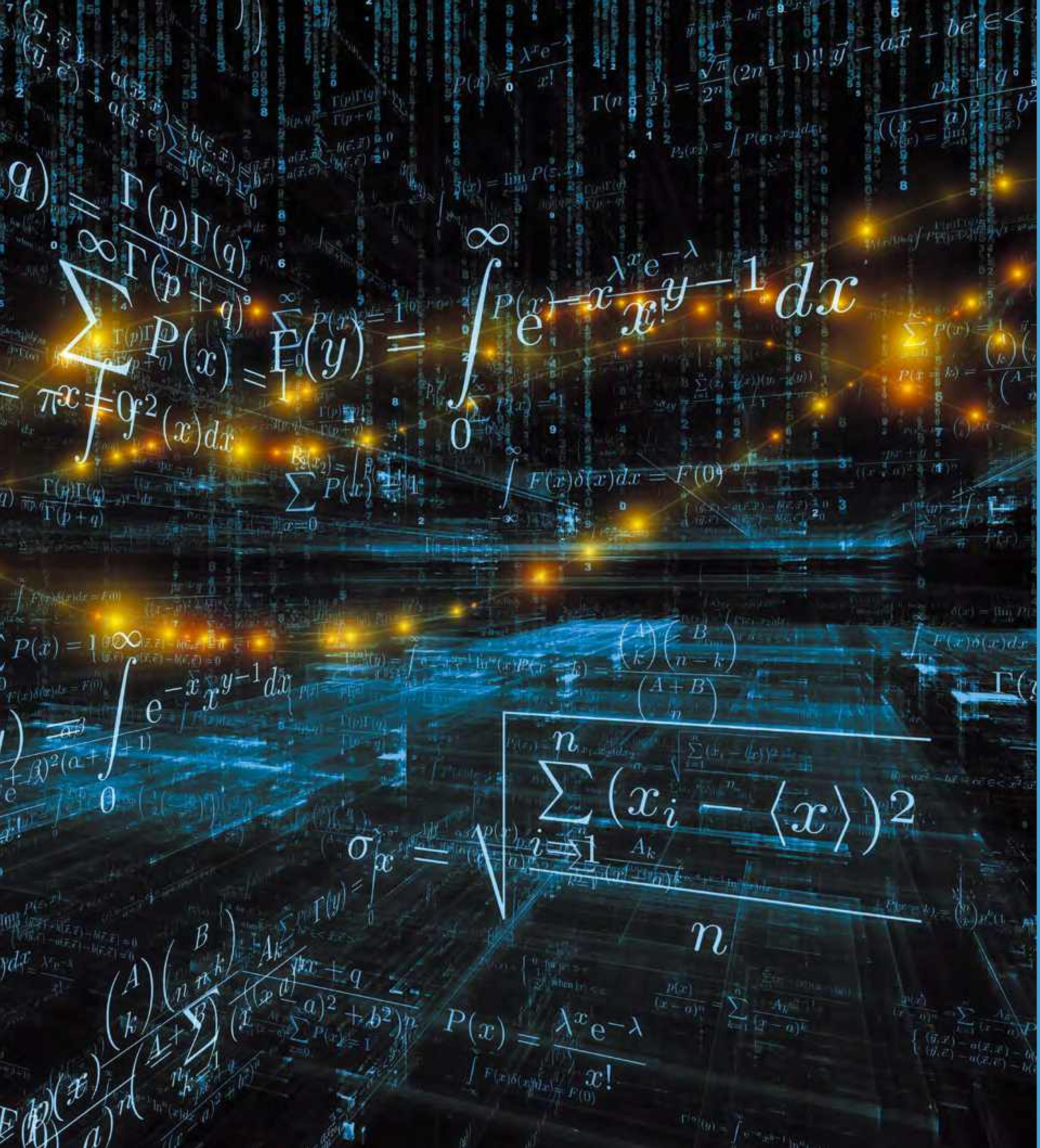

UDC 001.891.573

Creating a mathematical model of the General Planetary Vehicle: accelerating flywheels, passing the atmosphere, going into orbit

A. UNITSKY (Minsk), R. SHARSHOV, A. ABAKUMOV (Novosibirsk)

The main methods for calculating the General Planetary Vehicle (GPV) model that can be applied at the initial stage have been considered. First of all, general analytical methods are given, as well as the necessary GPV parameters (speed function; forces acting on GPV during take-off; etc.), the issue of the cost of total GPV mechanical energy and the required power of electric motors for the acceleration of the rotor on Earth is addressed. As an alternative to analytical methods, a finite element scheme of the GPV model (with possible parameters taken from an analytical calculation) is given, the behaviour of the model during take-off and exit to a given orbit is analyzed.

Keywords:
finite element analysis, General Planetary Vehicle (GPV), analytical model, GPV flywheel, dead weight dropping management, linear motor efficiency rate.

Finite element analysis is a modern advanced technique for calculating all possible structures and processes occurring in them. What used to require many hours of work to analyze any process, now causes no particular difficulties for professionals who are engaged in similar calculations. The essence of the finite element calculation is that the model or process is discretized by elements or by time, respectively. Or, a joint calculation of a discrete model is performed in time, taking into account the inertial component, as in this article. In general, the finite element analysis gives results that converge with real models with an accuracy of up to 5 % for a static calculation and up to 10 % for a dynamic one. The accuracy of the results obtained depends directly on the detailed elaboration of the design model.

This article considers the General Planetary Vehicle (GPV) model, a design version of which is presented in Figure 1 [1]. The authors modelled the dynamic behaviour during acceleration, the "release" of the structure and the ascent to a given orbit with the Earth orbital velocity for this orbit. In addition, a joint calculation was performed in the ANSYS software complex (finite element model) and Mathcad (differential equations of the structure behaviour at different stages of work). In general, the model consists of three tapes inextricably connected along the vertical axis (in the polar coordinate system) with specified properties: two tapes imitate the flywheels and the third tape, the rotor housing.

Discretization of the model is presented schematically in Figure 2.

Flywheel and shell structures are connected using a No Separation contact pair (with zero friction, without the possibility of separation), which eliminates the mutual influence of the flywheels on each other, but at the same time allows them to ascend together under the influence of the centripetal force.

There are several forces acting on the system, all of them are shown in Figure 3: F_1, F_2 are the elastic forces that integrate the scheme into a unified structure, G is the Earth gravitational force, Q is the atmospheric drag force, F – is the resultant of the F_1 and F_2 forces, $\dot{\varphi}$ is the angular rotor speed, φ is the angle of rotation of the system under consideration in relation to the axis of coordinates, ω_p is the Earth angular velocity (initial velocity of the housing rotation), δ is the central angle of the arc, $\dot{r}$ is the radial velocity of the rotor and the shell, r is the current radius of the rotor orbit, R is the Earth radius.

The main task solved in the work being quoted is the optimization of the masses of flywheels and the rotor housing based on the condition of determining the optimal efficiency rate and stabilization in a given orbit.

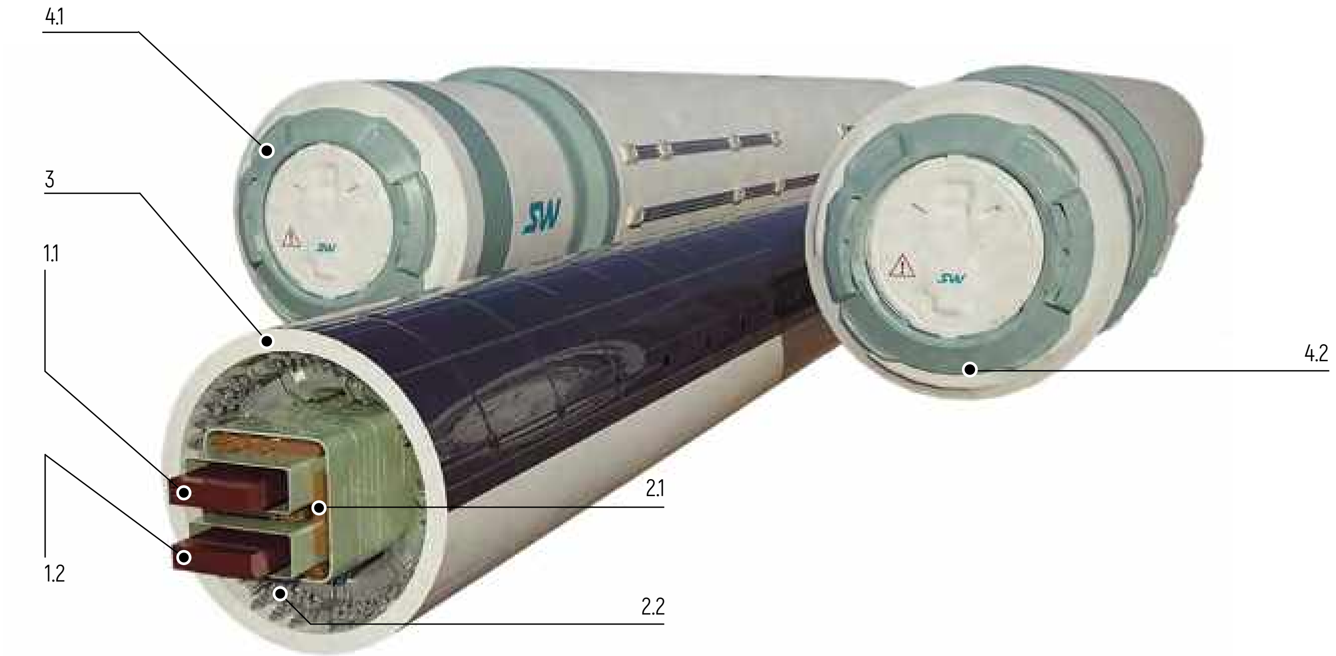

Figure 1 – GPV structure: belt flywheels 1.1 and 1.2; 2.1 and 2.1 drive systems located inside housing 3; external compartments (capsules) 4: passenger 4.1 and cargo 4.2

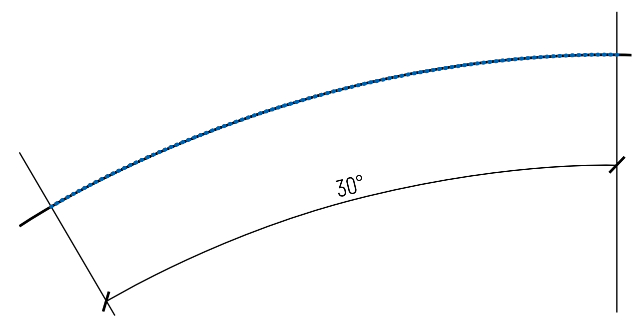

Figure 2 – Number of points on the surface of a sector with a 30° internal angle. The total discretization of the model is 1,000 points for each tape

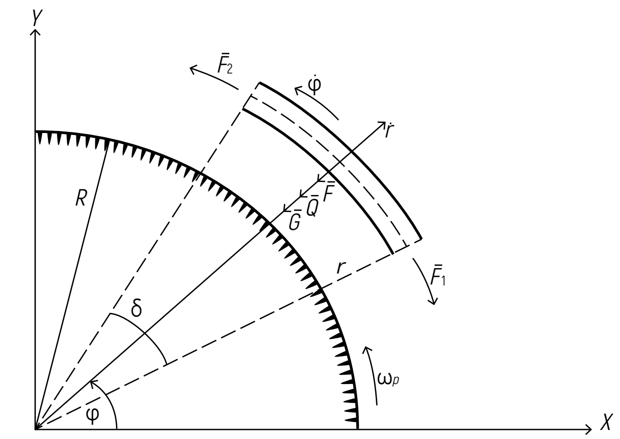

Figure 3 – Diagram of the effect of forces on the GPV segment

Parameters used in the problem being solved

Constant parameters:

$G = 6.67408 \times 10^{-11} \text{m}^3\text{s}^{-2}\,\text{kg}^{-1}$ – universal gravitational constant;

$M_{Earth} = 5.9723 \times 10^{24}$ kg – mass of the Earth;

$V_{1.e} = 465.1$ m/s – line speed of the Earth's rotation at the equator;

$R_e = 6{,}378.137$ km – Earth's equatorial radius;

$R_p = 6{,}356.752$ km – Earth's polar radius;

$T_e = 86{,}161.54933185$ s – period of the Earth' s rotationaround its radial axis;

$\rho_0 = 1.25$ kg/m^3 – atmospheric density at the Earth' s surface;

$V_1 = \sqrt{\dfrac{G \times M_{Earth}}{R_e + 415}} = 7{,}660.045$ m/s – Earth orbital velocity for a circular orbit of 415 km in height.

Parameters being set:

$E_{el} = \begin{pmatrix} 206 \\ 206 \\ 137.3 \end{pmatrix}$ GPa – moduli of elasticity of GPV elements;

$S_{el} = \begin{pmatrix} 0.057 \\ 0.026 \\ 0.064 \end{pmatrix}$ m^2 – cross-sectional area of GPV elements.

The modulus of elasticity of elements for flywheels is assumed to be equivalent to steel. The modulus of elasticity of the housing is assumed in accordance with GOST 10994-74 "Precision alloys. Grades", alloy H36 "Invar". Invar alloy in this case has a lower modulus of elasticity, a large relative elongation before rupture and is almost not subject to thermal expansion, in contrast to conventional steel. These parameters make this material more suitable for the rotor housing. According to these parameters, the final linear stiffness of the GPV segment is:

$C_{GPV} = \dfrac{1}{L_{GPV}} \sum_i \left(E_{el_i} \times S_{el_i}\right) = 0.548$ kN/m – linear stiffness of the GPV segment.

The design parameters are initially assumed on the basis of the optimal mass ratio of the housing and the flywheels, taking into account the initial efficiency rate of linear electric motors, which is 95 %

$m_{el} = \begin{pmatrix} 450 \\ 200 \\ 500 \end{pmatrix}$ kg – mass per unit length of elements (rotor 1, rotor 2, housing).

Relative initial rotor take-off speed:

$$V_{r.0} = \begin{pmatrix} 12.55 \\ -0.1 \\ 0 \end{pmatrix} \text{km/s.}$$

Absolute initial rotor take:

$$V_{a.0} = \left(V_{r.0} + \omega_1 R_0\right) = \begin{pmatrix} 13.015 \\ 0.365 \\ 0.465 \end{pmatrix} \text{km/s.}$$

The design model also includes the mass (dead weight) dropping management function and the frictional expansion management based on the Maxwell model with adjustable expansion resistance (Figure 4).

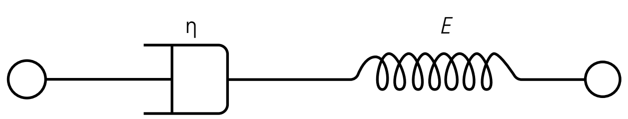

Figure 4 – Maxwell model for a visco-elastic damper. The viscous damper is connected in series with an elastic spring

Several forces influence the GPV element during take-off, calculated as follows:

– rotor centripetal force:

$$F_{r.r}\left(h, V_{el}\right) = \sum_i \left[m_{el_i} \left(V_{el_i}\right)^2 \frac{1}{(R_0 + h)} \right];$$

– gravitation:

$$G_i\left(h\right) = m_{GPV} \frac{gR_0^2}{(R_0 + h)^2};$$

– longitudinal force in the ring:

$$F_{c.\tau}\left(h, \Delta L_d\right) = C_{GPV}\left(2\pi h - \Delta L_d\right);$$

– elasticity radial strength in the ring:

$$F_{c.r}\left(h, \Delta L_d\right) = \frac{l_i}{L_{GPV}} F_{c.\tau}\left(h, \Delta L_d\right);$$

– aerodynamic resistance due to atmosphere:

$$Q_{атм}\left(V, h\right) = c_d\left(d_0 l_i\right) \frac{V^2}{2} \rho_0 e^{-\frac{h}{7.64\,km}};$$

– linear motor thrust:

$$F_{le}\left(V, t, i\right) = \left| k_v\left(t\right)_i \min\left(\left|\frac{W_{le}}{V}\right|, F_{max}\right) \right|.$$

Based on the above parameters and the first iteration of the calculation, the following system of equations was obtained.

Radial motion equation:

$$F_{r.r}\left[h\left(t\right) \begin{pmatrix} V_1(t) \\ V_2(t) \\ V_{sh}(t) \end{pmatrix} \right] - G_i\left(h\left(t\right)\right) - F_{c.r}\left[h\left(t\right), \Delta L_d\left(t\right)\right] -$$

$$-Q_{atm}\left[h'\left(t\right), h\left(t\right)\right] - M\left(t\right)h''\left(t\right) = 0.$$

Kinetic momentum change equation:

– for rotors:

$$F_{le}\left[V_1\left(t\right) - V_{sh}\left(t\right), t, 0\right]\left[R_0 + h\left(t\right)\right] -$$

$$-m_{r_0}\left[V_1\left(t\right)h'\left(t\right) + V_1'\left(t\right)\left[R_0 + h\left(t\right)\right]\right] = 0;$$

$$F_{le}\left[V_2\left(t\right) - V_{sh}\left(t\right), t, 1\right]\left[R_0 + h\left(t\right)\right] -$$

$$-m_{r_1}\left[V_2\left(t\right)h'\left(t\right) + V_2'\left(t\right)\left[R_0 + h\left(t\right)\right]\right] = 0;$$

– for the shell:

$$\left[F_{le}\left[V_2\left(t\right) - V_{sh}\left(t\right), t, 0\right]\right] +$$

$$+F_{le}\left[V_2\left(t\right) - V_{sh}\left(t\right), t, 1\right]\left[R_0 + h\left(t\right)\right] +$$

$$+m_{sh}\left[V_{sh}\left(t\right)h'\left(t\right) + \frac{d}{dt}V_{sh}\left(t\right)\left[R_0 + h\left(t\right)\right]\right] = 0.$$

Frictional expansion equation:

$$\frac{\eta}{l_i}\left(\frac{d}{dt}\Delta L_d\left(t\right)\right) - k_d\left(t\right)F_{c.\tau}\left[h\left(t\right), \Delta L_d\left(t\right)\right] = 0.$$

Initial boundary conditions of the problem:

$$h\left(0\right) = 0;\ h'\left(0\right) = 0;$$

$$V_1\left(0\right) = V_{a.0_0};\ V_2\left(0\right) = V_{a.0_1};\ V_{sh}\left(0\right) = V_{a.0_2};$$

$$\Delta L_d\left(0\right) = 0.$$

According to the data obtained from the solution of the system of equations and from the model, the diagrams presented in Figure 5 have been constructed.

The diagram in Figure 5 shows that the GPV rises to the given height (415 km above the level of the world ocean) and is stably located on it. The maximum vertical acceleration of the housing during take-off is 0.33 m/s^2, the horizontal average acceleration (peripheral around the Earth) is 2.04 m/s^2 (time of ascent to orbit is 6.8 × 10^3 s (Figure 7)).

For stable flight and fixation in a given orbit, various techniques and options were used. From the point of view of feasibility, the most optimal was the option of sequential transfer of energy from one flywheel to another. The relative velocities of rotors during take-off (in relation to the GPV housing) and absolute velocities of GPV elements during take-off are shown in Figures 6 and 7.

Upon reaching a given orbit, the velocities of all GPV elements (the housing and two flywheels) must be equal to the Earth orbital velocity for the given height (7660 m/s) in the direction of the Earth's rotation or in the opposite direction. In the process of transferring kinetic energy from one flywheel to another, a loss of energy occurs in linear motors, leading to the GPV destabilization (Figure 8).

The total value of losses in the process of transfer is 1.148 GJ per meter of length. To stabilize the GPV ring, the compensation of this energy is necessary. At this stage, hydrogen is supposed to be used to stabilize the scheme and add energy. The calorific value of hydrogen is about 140 MJ/kg. If we assume that the efficiency rate of a hydrogen fuel cell is about 50 %, then for each meter of the ring length, 16.4 kg of hydrogen will be required, it can be part of the ballast that is supposed to be loaded into the GPV cargo compartments.

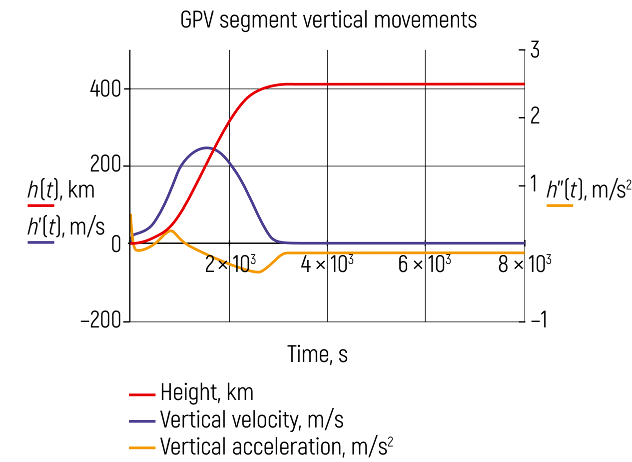

Figure 5 – Diagram of ascend, vertical velocity and vertical acceleration with time

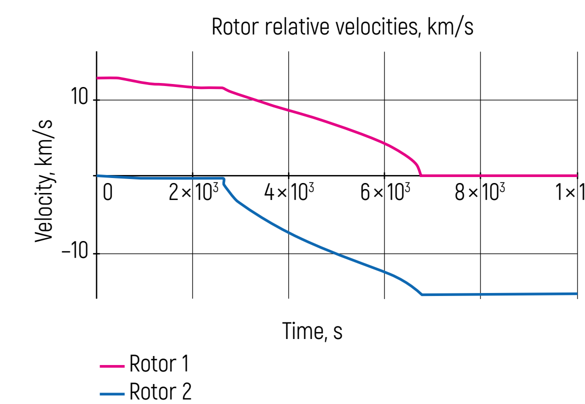

Figure 6 – Velocities of rotors during take-off (in relation to the GPV housing)

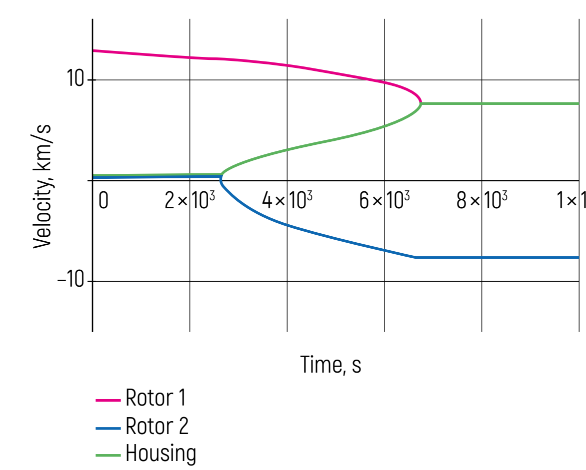

Figure 7 – Absolute velocities of GPV elements during take-off

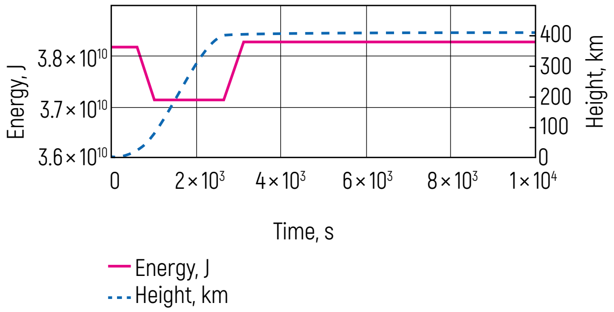

Figure 8 – Diagram of the full GPV mechanical energy in time

At the stage of further elaboration, it will be possible to optimize this process and to use, as an additional source of energy, a jet blast from the ballast cryogenic fluid, which heats up and thereby removes excess heat from the system. For this, it is permissible to use, for example, nitrogen or oxygen, cooled to temperatures of about –200 °C, which, when released into the atmosphere in the form of a jet blast, will not pollute it, but will be even able to partially restore the ozone layer (in the oxygen option).

The total energy costs for the initial spinning of the flywheels to the starting velocity are 1.42 × 10^{18} J. In the event that the 450 kg/rm rotor is accelerated up to 12.55 km/s in 20 days, then the required power will be 21.6 kW/rm. As the acceleration time increases, the required power decreases.

Diagrams of power consumed and generated (due to regeneration) during take-off are shown below in Figure 9, and the function of power on/off control at rotor drives during take-off is shown in Figure 10.

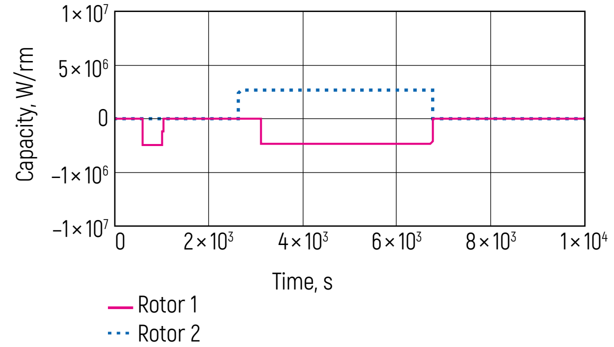

Figure 9 – Diagrams of power consumed during take-off, W/rm

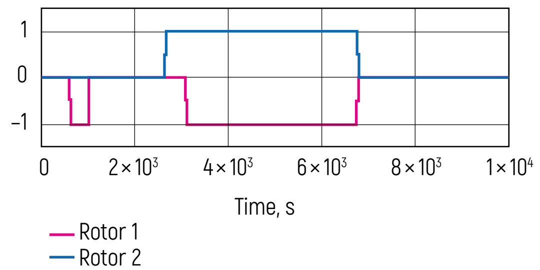

Figure 10 – Function of power on/off control on rotors during take-off

One more diagram should be drawn as a conclusion – the diagram of change in the total system energy during take-off (where the total energy loss of the system is also visible), from which conclusions can be made about its efficiency rate (Figure 11).

Energy losses during GPV take-off do not exceed 2.8 %, and taking into account the losses during the initial acceleration rotor (when the efficiency rate of linear electric motors is 95 %), the total amount of losses will not exceed 7.6 %.

Table – Comparison of options of different GPV arrangements

Option No.	Mass of GPV, rotor 1 / rotor 2 / housing, kg/rm	linear motor efficiency rate, %	Initial velocity of rotor 1, km/s	Efficiency rate of launching the GPV into orbit, %	Need for additional energy at launching the GPV into orbit, GJ/rm
1	250/225/500	90	15.65	92.4	2.43
2		95		96.3	1.16
3	450/200/500	90	12.55	94.4	2.27
4		95		97.3	1.16

Comparison of options of different arrangements, i.e. different ratios of flywheel masses and linear motor efficiency rates, should also be given (Table). Based on these data, it is possible to estimate the difference in the initial velocity, the total actual efficiency rate of launching into orbit and the need for additional energy at stabilization during take-off.

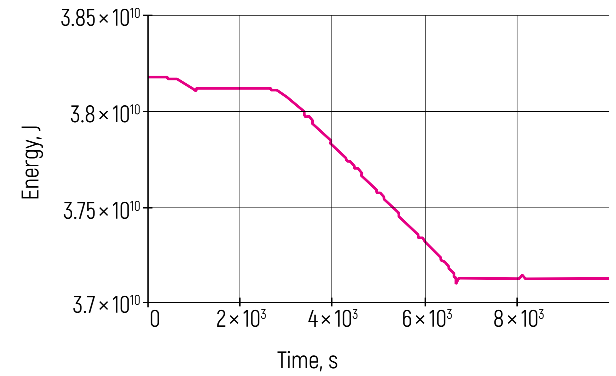

Figure 11 – Diagram of change in the total system energy during take-off

Thus, the best option is the option number 4 considered in this article: in terms of the starting velocity of the flywheels (which is lower than in the option with lighter flywheels), as well as in terms of the efficiency rate of launching the GPV to a low near-Earth orbit. In addition, it requires less energy to stabilize than other options. We would especially like to emphasize the vehicle's level of efficiency of the system – 97.3%, this value favorably distinguishes the considered project from any kind of geocosmic transport available today to humanity.

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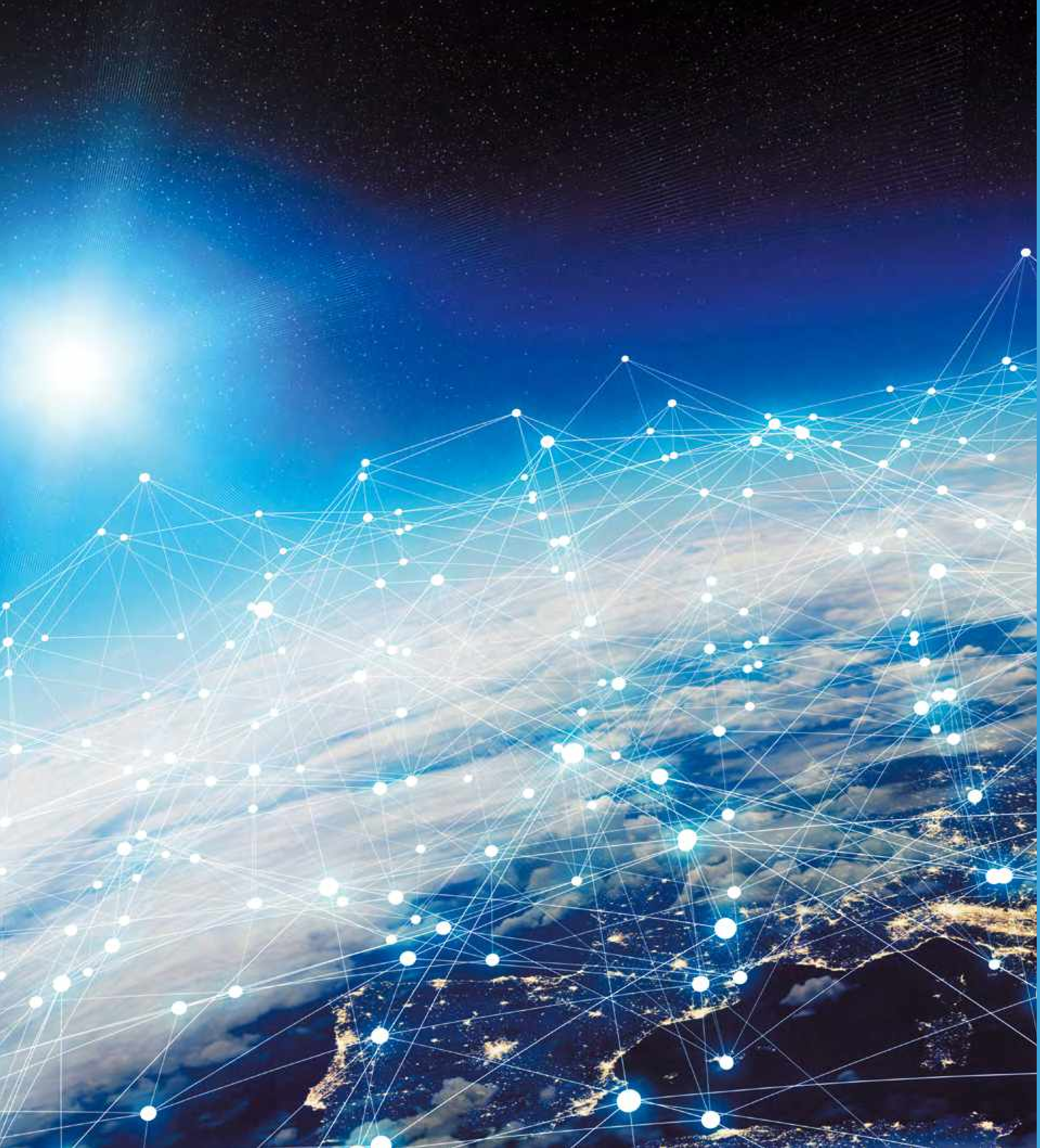


UDC 338.2

Innovative business models in the EcoSpace program complex

K. BADULIN (Minsk)

This article covers the major trends in the development of modern business and business models applied, including Data Science, big data, Industry 4.0, digital product development, and blockchain technology. It shows that EcoSpace programs, such as SkyWay and SpaceWay, are currently being developed in full compliance with the above trends. In addition, SkyWay and SpaceWay apply innovative business models and develop a fundamentally new approach to infrastructure projects that would become commercially attractive and would not cause severe damage to the environment.

Keywords:
EcoSpace, SkyWay, SpaceWay, business model, Data Science, Industry 4.0, big data, blockchain, infrastructure projects, digital product development.

In recent decades, the pace of progress made by science and technology has accelerated significantly. Numerous inventions that until recently were seen just as innovation projects have become the determining standards in existing industries. For example, mobile phones, digital photography, electric vehicles, etc.

There are numerous examples of companies that based their business models on the development of new technologies: Apple, Microsoft, Google, Amazon, Uber, Alibaba, etc. According to Forbes 2018 ranking, the Global Top 10 Companies measured by market capitalization included seven new-economy companies; Apple ($926.9 billion), Amazon ($777.8 billion), Alphabet (Google) ($766.4 billion), Microsoft ($750.6 billion), Facebook ($541.5 billion) and Alibaba ($499.4 billion) have been ranked as the top six [1]. The market capitalization of these companies already exceeds many times over the relevant figures for the major oil and gas corporations, banks, automobile manufacturers and retailers that traditionally held the leading positions in this rating until 5–10 years ago.

Data Science is becoming the centerpiece of the new economy to address the issues of analyzing, processing and digitizing information. Data Science was originally viewed as an academic discipline, and since the early 2010s as an interdisciplinary practical area. Besides, the job of a data scientist is considered to be one of the most attractive, highly paid and promising [2]. Data Science approach is to rely on data-driven decision making rather than on intuition- or experience-driven decision making. Data Science is none other than a generic name for the sum of technologies to produce data products, where value is added through data mining that extracts useful information intended for human consumption.

In the 1990s, data was not even considered an independent entity. In the 2000s, people started to refer to data as the "new oil." The phrase was first coined by British mathematician Clive Hamby in 2006. Numerous experts also repeatedly stated that, in the foreseeable future, data would gain greater economic significance than raw materials [3]. It is no coincidence that the term "data-driven" came into general use as applied to economy, programming, journalism, science and other areas.

The data-driven approach to economy has been actually implemented in the Industry 4.0 concept, which was proposed to the German government in 2011. The USA also adopted this strategy in 2014. The Industry 4.0 concept implies flexible control over the production scale and design process, artificial intelligence development, extensive use of "big data," mainstreaming of the Internet of things, blockchain technology expansion, cloud calculations, robotics, and augmented reality.

As a result of the industry's adopting the above principles, business models have also been undergoing changes. Now companies are striving to shift their focus from lean manufacturing to mass customized manufacturing based on agile principles and switch to manufacturing a single product, i. e. lot size 1. At the same time, the principle of economy is maintained: robot-driven manufacturing is more energy efficient and results in less waste and less rejected products [4]. As a matter of fact, lot size 1 can also be embedded into the production methodology of all EcoSpace programs. At the same time, the reshoring phenomenon is taking place, i.e. the process of returning innovative industries from the developing countries in Asia back to the developed countries in Europe and America.

Fully compliant with the Industry 4.0 concept, the EcoSpace complex programs, such as SkyWay and SpaceWay, are currently being developed. SkyWay and SpaceWay are applicable to projects aimed at creating, upgrading and expanding infrastructure facilities. However, private investors perceive large infrastructure projects as highly capital intensive ones, having low net present value, and long payback and return-on-investment periods [5]. SkyWay and SpaceWay are unique not only for innovative technological solutions, but also because they provide brand new business models for infrastructure projects.

In particular, the innovative SkyWay transportation technology is based on hundreds of unique technical, software and logistics solutions that can offer universal advantages: low capital and operating costs, environmental friendliness, safety, and high efficiency. SkyWay philosophy is based on the principle: transportation should solve problems rather than create them. Unlike conventional infrastructure projects, SkyWay projects are commercially attractive due to their short payback period, from three to five years. At the same time, the construction cost of the SkyWay transportation complex is 2–20 times lower as compared to traditional transportation modes [6].

It should be pointed out that the development of green technologies is a current global trend, and the transportation industry is no exception. In particular, global sales of electric vehicles are growing exponentially [7], a number of automobile manufacturers have already announced that they will stop developing new models powered by internal combustion engines in 8–10 years, and several European countries plan to ban them in 2025–2030 [8]. Therefore, the environmental friendliness of SkyWay is one of the key advantages of this technology, in addition to saving materials during the construction of overpasses and energy-efficient operation of innovative rolling stocks.

Besides, one of the SkyWay sustainable competitive advantages is the use of digital product development based on Dassault Systèmes' 3DExperience platform. Thanks to the platform, a digital mockup can be created for each transportation vehicle and system. This allows early requirements validation, minimization of incoherence between different services when amending the design documentation, and virtual tests. Hence, the product development time is significantly reduced, and the product cost estimation process is simplified.

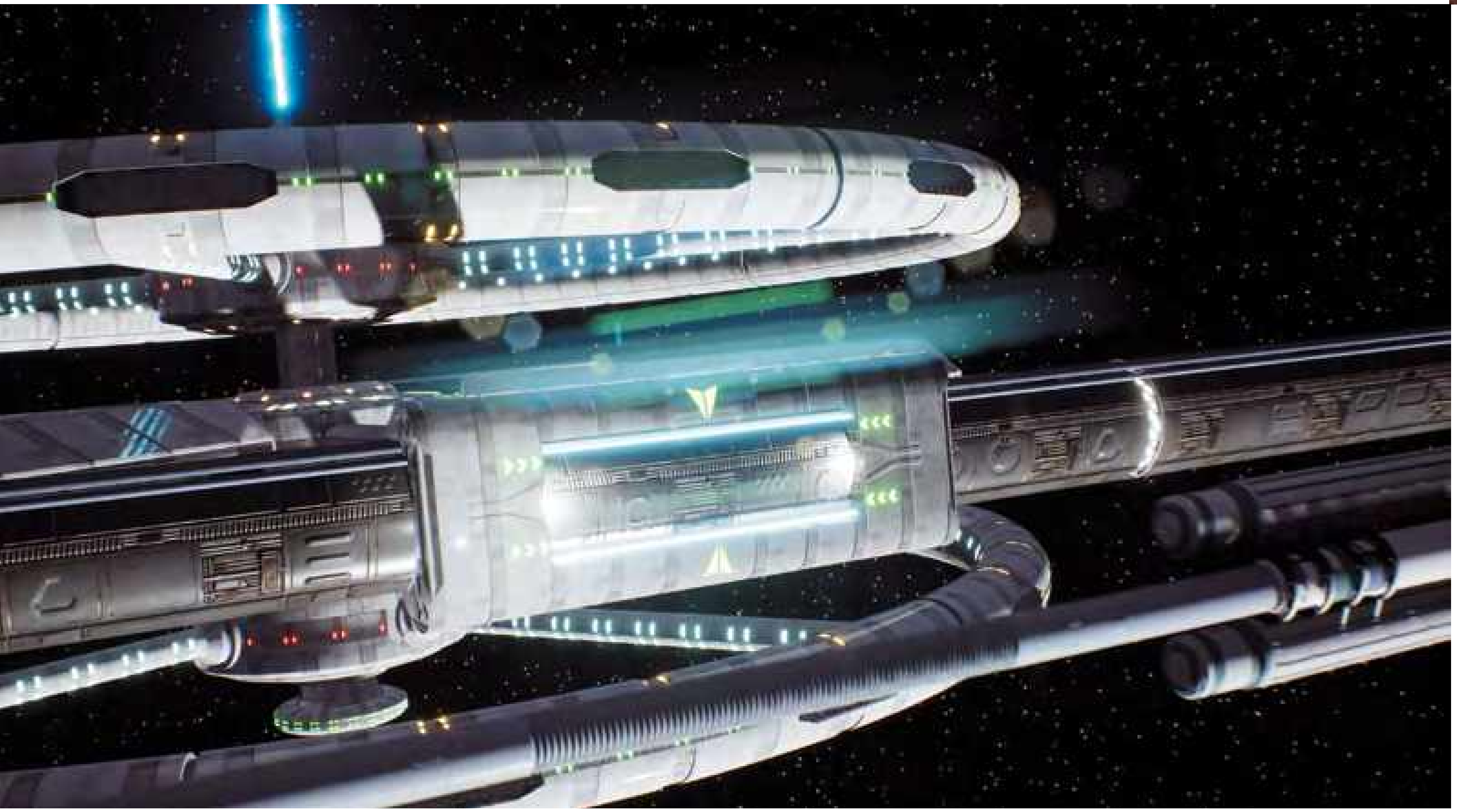
Another important component of the SkyWay business model is the extensive use of big data and blockchain technology. The SkyWay transportation system is controlled by an intelligent unmanned system. Its significant component, a sensor system, allows 24/7 cargo and passenger tracking. The system uses blockchain protocol to process and store data, including the cargo and passenger transportation history, and special software with data access delimitation. Total package smart contracts for the procurement, cargo transportation and escorting mitigate the risk of fraud, data breaches and payment errors.

Due to the use of the innovative business model, SkyWay's share in the global transportation market is expected to reach 50 % by 2100 [6], repeating the pattern of railways in the XIX century and highways a century later. The share of obsolete conventional roads will gradually decrease as new and more efficient solutions will predominate.

The same can be referred to SpaceWay, i.e. non-rocket space exploration program, based on the geocosmic transportation system sharing the same name. On the one hand, the creation of SpaceWay will facilitate bringing the environmentally harmful component of the technosphere into the near space, with the planet's biosphere being left for life on Earth. On the other hand, the innovative business model will turn SpaceWay into one of the most commercially attractive projects in the human history. Space industry will open up new opportunities in metallurgy, solar power, and mining.

The SpaceWay business model is based on the cargo and passenger transportation into the near space and back. There are plans to integrate it with the global SkyWay and HyperU road network, including intra- and intercontinental transportation complexes. The SpaceWay business model is geared towards cargo and passenger transportation to low Earth orbit at a price 10,000 times lower than that in the existing space industry [9]. This can be considered the cornerstone of the project's commercial attractiveness. Another unique SpaceWay feature is the negative cargo and passenger transportation cost, starting with the tenth year of operation. Therefore, due to the cargo and passenger transportation, SpaceWay can generate additional profit for its stockholders.

Thus, we have considered the key trends of modern industry, including the peculiarities of SkyWay and SpaceWay development. Both programs apply innovative business models that can significantly minimize costs without causing any environmental damage. With all that said, it seems likely that there are all the prerequisites for successful implementation of the EcoSpace complex programs.



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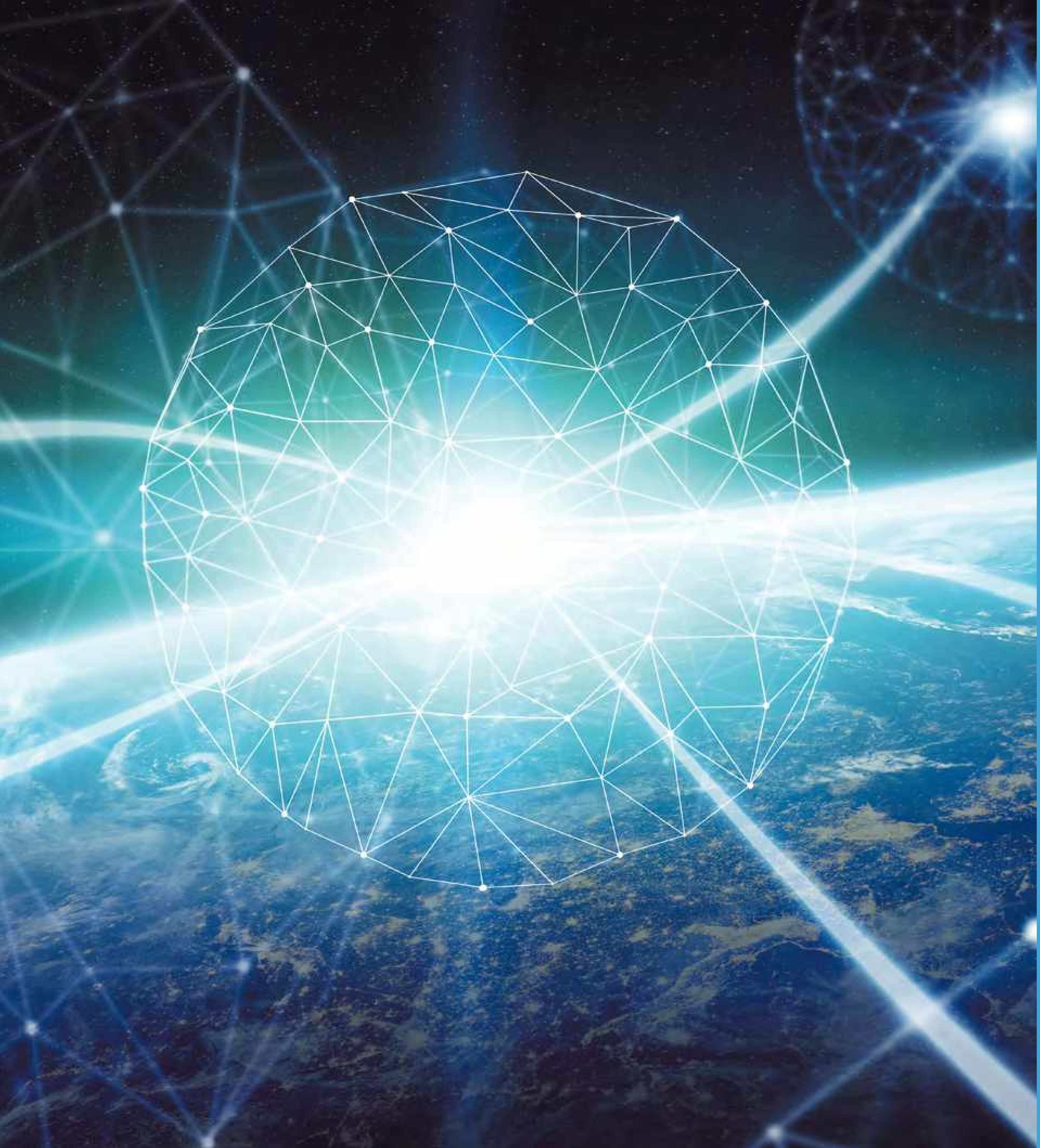

UDC 004

Blockchain as a single information and economic basis for an Equatorial Linear City, its transport systems and General Planetary Vehicle

E. KABANOV (Moscow)

The article describes the role of decentralized computing system technology – blockchain – in the formation and sustainable development of linear cities and new economic models of space systems. The ways of connecting economy, transport systems, telecommunications, energy, mutual settlements, as well as automated settlements between suppliers and consumers of energy and electrical capacity anywhere in the world without entering into legal contracts with a telecom operator, without the guest network and roaming, are presented. The principles of blockchain environment with interacting contracts are described, which allow connecting seamlessly and flexibly the receipt of goods and services with their payment, and which ensure a fair distribution of income from activities in the form of joint stock companies of a new type – decentralized autonomous organizations (DAO).

Keywords:
blockchain, decentralized computing systems, Equatorial Linear City (ELC), automated calculation, blockchain environments, decentralized autonomous organization.

The rapid development of cities has given rise to many challenges, including the unbalanced distribution of resources within countries. The trend towards urbanization has led to the emergence of densely populated metropolises with poor quality of life, poor ecology and transport collapse. On the other hand, desolation and even under development of vast territories, impossibility to attract investments and labor force to depressed regions.

Recently, there have been improvements: many states and global corporations have taken a course to implement "green" solutions in key business processes. A number of countries have programs in place to support people who have decided to move from the metropolis to less populous and less developed places and start their own businesses there. Leading engineers, architects and designers are designing the cities of the future, and many ideas (for example, the use of solar panels as the main "fuel") are beginning to materialize right now.

One of the most successful concepts is considered to be the linear city, which is a network of high-rise towers separated from each other by 500 m and connected by horizontal stringed roads – SkyWay transport system [1]. According to the project, all transport, energy and information communications are located at the second, above-ground level. And the first level – that is, the ground itself – remains a protected territory and is intended for pedestrians.

The author of the concept, an engineer, the creator of string transportation systems technology, Anatoli Eduardovich Unitsky, in addition to string transportation, is engaged in the implementation of SpaceWay program on non-rocket space industrialization, the components of which are the Equatorial Linear City (ELC) and General Planetary Vehicle (GPV) [1].

An Equatorial Linear City is a cluster city that runs along the equator and consists of an extensive network of transport, energy, engineering and IT infrastructures. The launch of this project is one of the key stages of the program: the Equatorial Linear City will serve as the basis for the creation of General Planetary Vehicle – affordable and environment friendly transport, allowing the exploration of near space without the use of rockets, the launch of which has a devastating impact on the environment (the ozone layer is being destroyed, the earth, water and the atmosphere is being polluted by the products of fuel combustion and the debris) [2].

In addition to the architectural appearance, transport, energy and communication systems, the coming technological changes will also affect the economy of cities. The dominance of bureaucracy and corruption, the development of monopolies that "stifle" medium and small businesses, slow decision-making, and the transformation of potentially profitable projects into long-term construction due to lack of financing are the key problems faced by residents of modern metropolises.

In the context of solving emerging issues, it can be assumed that many economic decisions in the cities of the future will be based on blockchain technologies. The Internet has changed the world by making the exchange of information fast and convenient, connecting people from different countries and continents through computers and mobile devices. The Internet has greatly simplified a huge number of processes: no longer need to call taxis to order a taxi at an optimal price or spend a lot of time searching for a particular product, visiting retail stores located in different parts of the city. Paper accounting, which caused a lot of problems for companies, especially for large ones, with a lot of branches and subdivisions, has also become a thing of the past.

Blockchain technologies face a complex task: to develop a single and open standard that will unite all financial transactions into a system, reduce the time of their execution and the number of intermediaries, as well as greatly facilitate control over the distribution of funds. Investors of blockchain technology are given an opportunity to expand the range of potentially successful projects that are difficult to monetize in the current situation.

Blockchain technology makes it possible to combine economy, transport systems, telecommunications and energy. It can be used to regulate relations between state authorities, investors, organizations, suppliers, consumers and other stakeholders. The key concept in this system is a token.

The token is an accounting unit used to represent the digital balance in an asset. The tokens are recorded in a database based on blockchain technology and are accessed through special applications using electronic signature schemes [3]. The tokens simplify mutual settlements and fully automate them. Today there are two types of tokens – Utility and Security. Utility-tokens are digital coins used to pay for a particular service. The Utility-token can be compared to a token used for subway travel, but outside this system, outside the subway, has no value. Security-tokens are digital analogues of securities, which give the owner the right to receive dividends and profit share.

Preparing for an initial public offering (IPO) is time-consuming and tightly linked to specific countries and exchanges, and companies and purchasers of shares have to use expensive intermediaries, such as auditors and brokers [4]. The IPO path is suitable only for large corporations with multimillion turnover in recent years. In particular, for a corporation that owns a network of railways, trains, railway stations and other assets both inside and outside the country.

At the same time, STO (Security Token Offerings) does not take much time, and the number of intermediaries accompanying the process is much lower. This way of attracting investment is suitable for promising startups, medium and large businesses that cannot access the IPO. Security-tokens can be traded on stock exchanges around the world under legal conditions. In other words, investors from different parts of the world can finance a local transport project – for example, a linear transport system implemented in the United Arab Emirates.

It should be noted that modern transport networks of different countries are mostly monopolies. The list of companies participating in the development of urban systems for passenger and cargo transportation is narrowly defined and does not function according to the rules of free competition. Because of this, potentially successful projects, including those using "green" technologies, remain unimplemented.

Blockchain technologies allow different owners to create new infrastructure objects, adhering to transparent rules of competition and pricing. Moreover, the accession of new participants in the creation of the transport system to the existing ones does not lead to the revision of the previous agreements and confusion in mutual settlements.

One of the options for regulating the relationship between participants is as follows. With the help of smart contracts, payments made by passengers are automatically distributed among participants. The amount of charges depends on the carrying capacity or the frequency of resource consumption. Such deductions form the income of companies providing services or participating in the creation of infrastructure facilities. Such an economic system can be used to implement the Equatorial Linear City.

This approach is suitable for both individual (automobile, rail) and various public transport systems: from bicycle sharing and carsharing to complex ropeway, rail and string systems, as well as for organizing the movement of space cargo along the Equatorial Linear City and beyond. The smart contracts can provide a transparent, efficient, universal and monopoly-free way for a multiple use of the transport system by a variety of users – both individuals and transport companies, individual countries and international alliances.

The Internet of Things (IoT) technology should also be considered [5]. It is a concept that involves the interconnection of things and objects into a global network under the control of artificial intellect, their interaction with each other and with the environment by means of built-in sensors, detectors, radars and lidars. Human participation in this system is minimized [6]. The most notable projects in this area are the development of autonomous cars based on artificial intelligence, a race in which major corporations of Google, Yandex, Tesla, Waymo and other automobile and technological giants are involved.

Blockchain provides an opportunity to link tokens with each detector, radar or lidar, thus making the calculation system as transparent as possible [7]. Let's consider an example: a train driven by artificial intelligence moves on track sensors. It passes through plots belonging to different companies. Scanning the authenticators of the sensors, the system automatically transfers the owner the corresponding number of tokens as payment for travel on the plot. Such a system helps to avoid time delays, errors and minimizes the negative impact of the human factor. Besides, blockchain is also able to secure things and objects using cryptographic methods. Thanks to this system, the rails of the SkyWay transport network will not be able to be used without proper maintenance, forged or replaced by a low-quality analogue.

Blockchain technology can also be used in the energy sector. Blockchain allows setting up an automated calculation of suppliers and consumers of thermal energy and electric capacity – and achieving fairer tariffs, formed by natural market rules, without artificial regulation [8]. In the new system, consumers, generating companies and grid companies will be able to connect to the unified energy network using

an automatic metering device. Blockchain micro-payment technology will provide controlled energy supply through interaction with the blockchain contract. As in the transport system, the balance of supply and demand will be formed dynamically, in real time, which will ensure competition between prices and conditions on the exchange principle.

Transport (e.g. trams), which is operated by a private company, is equipped with an individual energy metering device and is connected to the network on a permanent basis. The device provides access to the consumer's smart contract. In order to ensure that power is supplied from the grid, the vehicle owner needs to maintain a certain balance of tokens. As the vehicle moves, the meter detects the current flowing through it, records the time and calculates the operation. The meter registers the amount of electricity consumed in the smart contract and writes off the tokens according to the tariff. The ELC itself is a consumer of electricity, but in conjunction with General Planetary Vehicle (when "solar" electricity with negligible cost from orbit will is supplied to Earth) can be a kind of energy hub that sells electricity.

Blockchain technology will organically enter the sphere of telecommunication services, simplify and transform it [9]. Blockchain will provide access to the global network and information resources anywhere in the world without entering into legal contracts with a telecom operator. Such concepts as "guest network" and "roaming" will also become a thing of the past.

The new principle of communication organization puts the mobility of the user first [10]. Phones, tablets, laptops and other gadgets are able to independently detect the available networks, determine the best option for connection and automatically agree on a mutually acceptable format of payment, as well as to determine the cost. In such a system, any device can be either a data-consuming subscriber or a provider that provides access to neighboring users and receives a commensurate fee for services provided. In the future, it is also possible to sell telecommunication services provided using equipment installed on the Industrial Space Necklace "Orbit" (ISN "Orbit").

In conclusion, it should be noted that blockchain-environment principles with interacting contracts allow for a seamless and flexible link between the receipt of goods and services and their payment, the formation of competitive market principles where this was not possible, and the fair distribution of income. This was made possible due to the decentralized autonomous organizations (DAOs) [11]. Unlike ordinary companies that follow a rigid hierarchical structure, DAO consists of equal participants, each of which has unlimited access to information. This is the most democratic version of the organization that exists today.

Exactly these principles can be used in the basis of the economic system of the Equatorial Linear City of the future, and later used in the SpaceWay software complex and in all its subprograms: ELC, GPV, ISN "Orbit".

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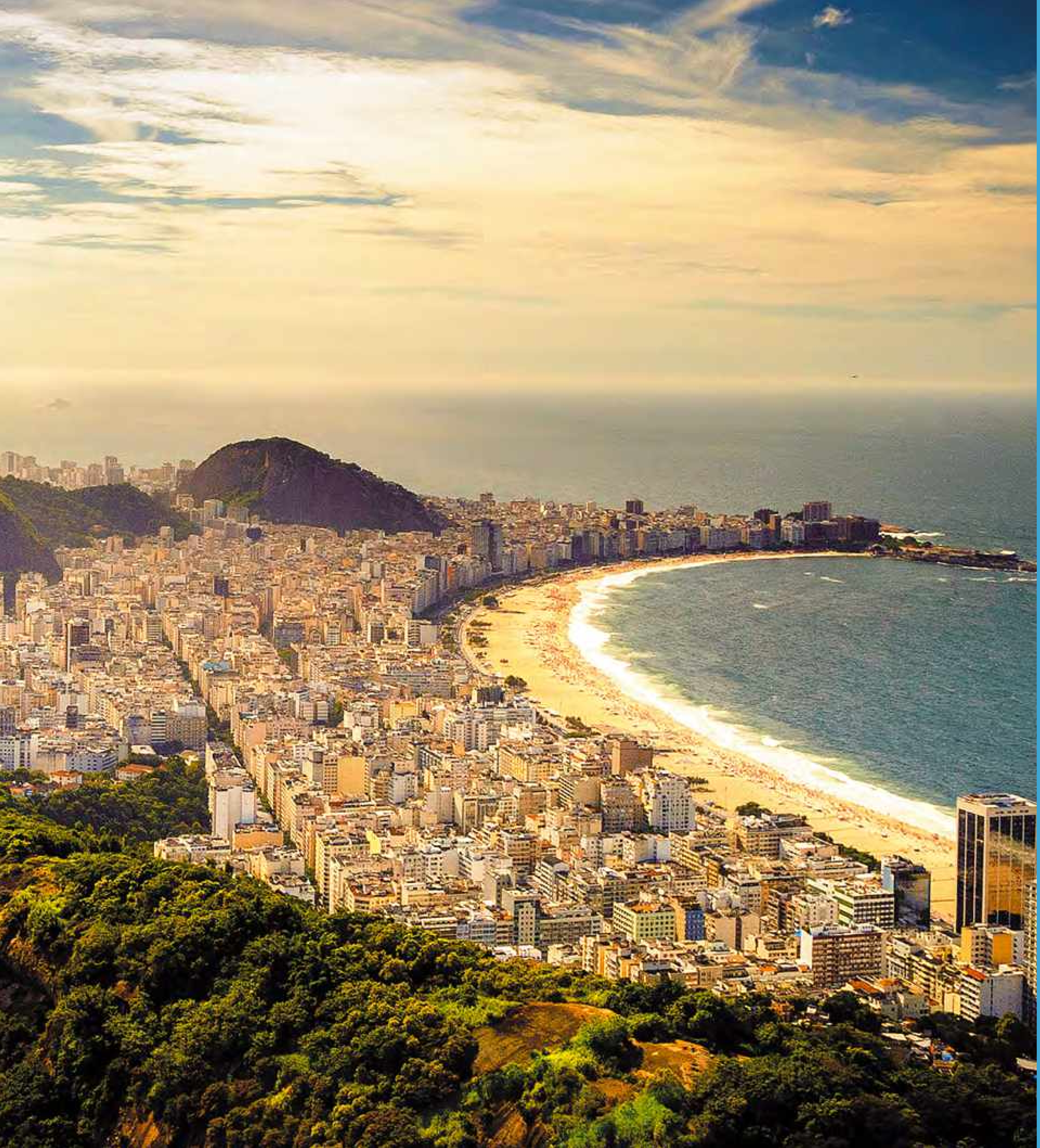


UDC 332.13

Economic efficiency justification of SpaceWay program implementation for the participating countries on the example of Brazil

A. UNITSKY, S. VOLOSHINA, V. LAVRINENKO (Minsk)

The article discusses the possibilities of economic growth in Brazil through creation of the General Planetary Vehicle (GPV) on its territory. The country's current and forecast economic situation, hydropower and human resources potential have been studied. It has been established that four main development directions could be cost-effectively implemented as a result of the GPV construction: creation of a new transport infrastructure generation; obtaining of a quality product of space industry; use of space raw materials; operation of the GPV as a giant linear kinetic power plant. The economic efficiency of SpaceWay Program implementation, which will exceed a trillion dollars a year for Brazil, has been analyzed.

Keywords:
SpaceWay Program, General Planetary Vehicle (GPV), space industry, economic efficiency, Equatorial Linear City (ELC).

Space is an endless universe for innovation and scientific-technological progress. The volume of the world space services market today is about 400 billion USD per year and it annually grows by 4–5 %. With the arrival of new types of launch vehicles and the introduction of promising technologies, the growth of this market is projected to accelerate, the volume of which may increase to about 1.5 trillion USD by 2030 [1]. Along with the high economic efficiency of this business type, space research has a serious impact on the environment, causing irreparable damage to the biosphere. Relevance of the topic under consideration, in addition to the need to build General Planetary Vehicle (GPV) to save Earth and human civilization, depends on the fact that space industrialization is economically super beneficial.

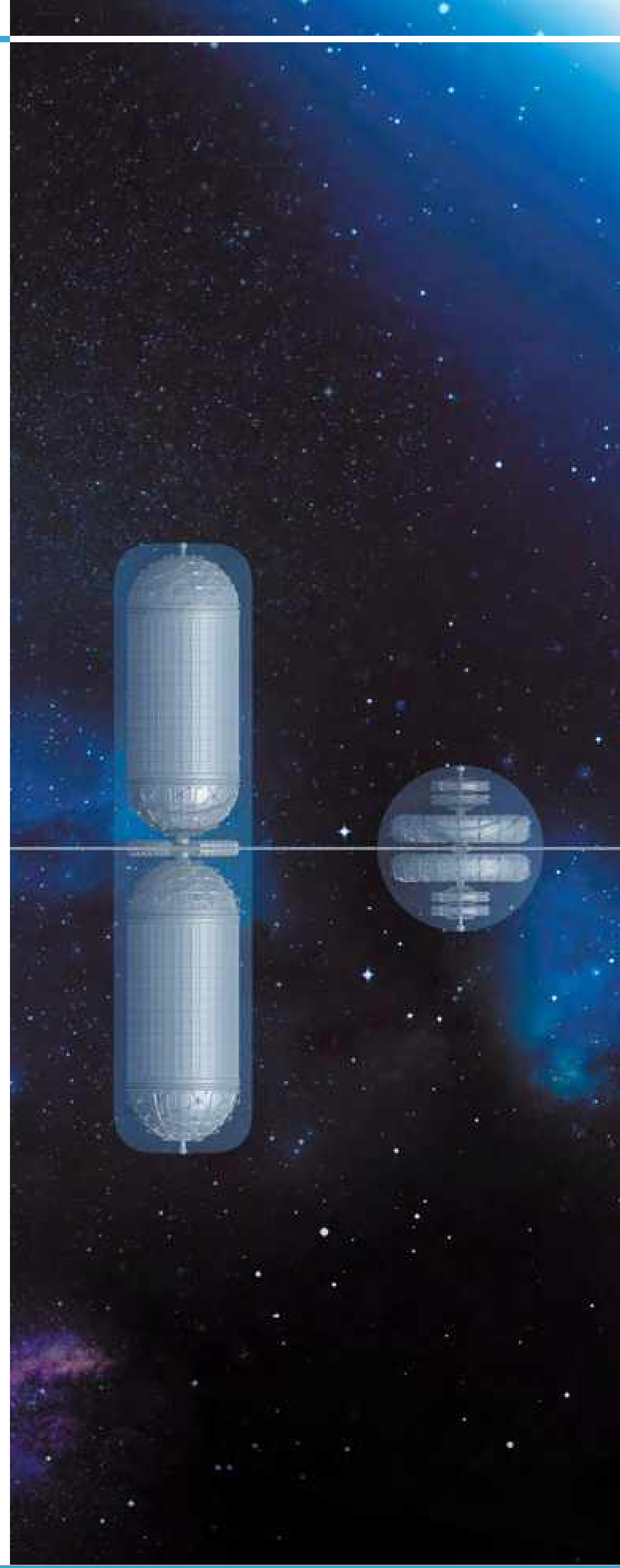
The purpose of this work is to study the need to create new infrastructure by building modern production facilities in space with the aim to prevent environmental problems on the planet and derive economic benefits for all mankind. For this purpose, it is necessary to justify the practicability and cost-efficiency of SpaceWay Program implementation for all the participating countries on the example of a particular country, for which Brazil was chosen. This work will allow identifying and considering resource capacities for the GPV construction, predicting the qualitative and quantitative effects from SpaceWay Program implementation.

General Planetary Vehicle is a reusable geocosmic transport and infrastructure complex for non-rocket near space exploration in order to create and operate the near-earth space industry. The GPV, using only the internal forces of the system, is capable of launching loads into various circular equatorial orbits by keeping its centre of mass unchanged in space. The GPV is the only possible environmentally friendly system for geocosmic transportation from the viewpoint of physics laws [2].

As a result of the GPV construction, four main directions of economic development will be realized.

1. New generation infrastructure development, as well as the development of modern, advanced, highly efficient and environmentally friendly transport capable of carrying about 10 million tons of cargo and up to 10 million passengers into orbit in one flight, while modern cosmonautics would require more than 10 thousand years doing it.

2. Obtaining a higher quality product of space industry in comparison with earth production (weightlessness enables the production of unique materials, mechanisms and equipment; vacuum combined with weightlessness



promotes production development of unique ultra-pure and super strong substances and materials).

3. Consumption of space raw materials – extraction of nickel-iron ore, platinum, cobalt and other minerals from asteroids; their subsequent delivery to Earth orbit.

4. The use of solar energy and other energy resources of space. For example, the excess of the reverse cargo flow over the direct one will allow converting the potential and kinetic energy of space cargo into electricity by means of the GPV.

The GPV construction is a global program worth over 2 trillion USD [2]. In the case of an equatorial location, the starting trestle will pass through the territory of 13 countries and will be more than 40 thous. km long. Ideally, the whole world shall unite to implement this project. However, if we proceed only from the resources required for the GPV construction, then Brazil's potential that is already available today enables this project to be realized.

1. Brazil is one of the top ten countries in the world with the largest economies. The budget for 2019 was approved in the amount of USD 616 billion (after a significant growth in 2007–2008, the developed Brazilian economy decreased by 0.3 % in 2009). However, in 2010, it demonstrated impressive rates of economic growth of 7.5 %. According to experts, the Brazilian economy will have a growing trend in 2019–2020, with a forecast growth of 2.3 % and 2.5 % respectively [3].

2. The country has a huge hydropower potential (the initial energy reserve required to lift the GPV is 4.2×10^{11} kWh; in fact, Brazil produced 5.9×10^{11} kWh in 2017) [4].

3. The basis of the Brazilian economy is formed by mining and manufacturing industries (the possibility to load existing production capacity and attract highly qualified experienced personnel to work in space).

The methodology for calculating the economic effect from the project is based on the following assumptions: the effect is calculated as the difference between two versions "with and without taking into account the project"; in the "without taking into account the project" version, the growth forecast is based on positive dynamics and economic situation improvement; the "with taking into account the project" version implies the use of the most advanced technologies. The direct calculation does not take into account lost profits and other indirect indicators, as well as various social, political and environmental effects.

Calculation of the economic efficiency of the program implementation in Brazil:

1) the economic effect from the GPV use for geocosmic transportation is determined by the difference in transportation cost of existing launch vehicles and the GPV. Currently, this difference reaches about 10 million USD/t (based on the lowest weighted average prices of cargo delivery into orbit by rockets). Based on the planned volume of transportation of about 100 million tons of cargo in the first year of the GPV functioning, the economic effect will amount to 1000 trillion USD (received in 20 years with a discount of 25 %; in the current cost of money, it is only 11.5 trillion USD) [2];

2) establishing industrial enterprises in the Earth orbit, scientific laboratories, plants, factories, workshops in the field of power engineering, mechanical engineering, metallurgy, chemistry, electronics will result in an economic effect from the production and sale of unique upmarket products for the value of over 20 trillion USD per year: products of ferrous and nonferrous metallurgy, including foam steel and superconducting materials, biopreparations, medicines, parts and equipment for all types of industries, robotics, mobile phones and communication systems, various types of IT-equipment;

3) space has unlimited raw material resources; it is planned to extract iron ore, platinum, cobalt, gold, manganese, molybdenum, nickel, osmium, palladium, rhodium and other minerals from asteroids. A relatively small metal asteroid with a diameter of 1.5 km may contain various metals, including precious ones, worth 20 trillion USD. An asteroid with a diameter of 1 km may contain up to 2 billion tons of iron-nickel ore (about 112 billion USD in money equivalent [5]);

4) when space industry is loaded at full capacity, the reverse cargo flow from the orbit to the planet will significantly exceed the direct cargo flow, which will allow converting the potential and kinetic energy of space cargo into electricity. Due to this phenomenon, the cost value of transportation will become "negative". This means that the geocosmic GPV complex will be profitable not as a transport means, but as a giant linear kinetic power plant with a net energy profit of about 200 USD per ton of excess cargo, i.e. 400 million tons of excess cargo per year will provide a net energy profit of 80 billion USD;

5) a huge logistics center for the distribution of space products in North and South America can be built in Brazil

in order to organize optimal material flows. Highly developed transport infrastructure will allow efficient multimodal transportation. The annual economic effect from its functioning will amount to more than 100 billion USD;

6) the creation and use of the TransNet transport and infrastructure complex with a length of more than 2,000 km (high-speed, urban and hyper-speed routes), combined with the GPV starting trestle, will allow to get an annual economic effect from passenger and cargo transportation of more than 100 billion USD, which will increase with due regard of the growth in demand for space products and the effective functioning of the logistics system;

7) the construction of a linear pedestrian city of a cluster type along the GPV starting trestle will move the population to an ecologically clean area, which will boost safety, improve life quality and save resources. In addition, the prestige as well as investment and tourist attractiveness of the area will enhance. The annual economic benefit from this factor will amount to more than 100 billion USD.

The economic benefit from the functioning of SpaceWay Program as a single complex will allow surpassing the result that can be received from the use of each of its components separately (Equatorial Linear City, General Planetary Vehicle, Industrial Space Necklace "Orbit"). In this way, the synergetic effect from space industrialization will manifest itself, which for Brazil will reach more than a trillion dollars a year.

Along with a large number of advantages, the process of large-scale construction still has certain drawbacks: the forced cutting down of a part of the forest and the withdrawal of agricultural land from circulation in order to form the necessary land allotment with a safety strip; caused discomfort for marine creatures in the construction zone in water areas. However, the construction process, which is carried out within the framework of environmental safety standards, guarantees the minimization of harmful impact.

The technological development path has led to many negative changes in the biosphere. The only way to prevent its irreversible degradation, and consequently the degradation of all mankind, is to move the technosphere beyond the biosphere which stands for space industrialization.

Thus, the GPV construction will provide the technosphere with a niche outside the biosphere, and will also make it one of the most commercially attractive projects in human history. In the process of studying the available resource potential necessary for the GPV construction in Brazil, the authors of this article have identified promising areas of the development and made their economic assessment. It is expected to obtain economic benefits from the creation of a new generation of high-performance transportation infrastructure, the possibility of obtaining a unique and upmarket product of space industry, the availability of the use of raw materials and energy resources of space, the functioning of the GPV as a giant linear kinetic power plant, as well as the construction of a linear pedestrian city, which, along with the prevention of environmental problems, secures economic efficiency from SpaceWay Program implementation.

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UDC 330.332.55

Space industrialization is a new era of human development and a necessary step to save the Earth's biosphere (economic justification)

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The article considers the original approach to the substantiation of the space vector of industrial development. The author puts forward the hypothesis of the absolute competitive advantage of the economy of industrial space and the goods and services it produces. The hypothesis explains the investment attractiveness of the industrial space economy and the mechanism of competitive elimination of the economy of the technosphere, and first of all the industries that most heavily pollute the biosphere and deplete natural resources. In his substantiation, the author relies on the fundamentals of classical economics, the specificity of the technological conditions of the space environment, and other circumstances that provide the space goods and services with an absolute price and quality competitive advantage.

Keywords:
technosphere, biosphere, General Planetary Vehicle (GPV), industrial space economics, absolute competitive advantage, driver industries.

Since the 50s of the last century, mankind has begun to feel the pollution of the environment and the limited natural resources caused by the oppressive effects of the Earth's technosphere. In 1972, at the UN conference held in Stockholm, the international community recognized the reality of an environmental and resource catastrophe. Soon the concept of "sustainable development" was put forward, when "meeting the needs of the present time does not undermine the ability of future generations to meet their own needs" [1]. However, even after half a century, economics has not come to a common understanding of the ways of practical implementation of this concept.

The only unlimited source of resources is space. However, rocket cosmonautics, which annually delivers no more than 1 g of cargo to orbit in terms of each inhabitant of the Earth, is not able to provide a significant increase in its cargo traffic for a number of reasons. However, a General Planetary Vehicle (GPV) proposed in 1982 by engineer A. Unitsky is capable of raising to near-Earth orbit in one flight and deliver back up to 10 million tons of cargo and up to 10 million passengers [2, 3]. GPV does not change the position of its center of mass relative to the center of mass of the Earth in the course of operation, with which it coincides, uses electrical energy, and also is able to transform the kinetic and potential energy of its own design and cargo into each other, which ensures a thousandfold decrease (compared to rocket carriers) of specific energy and, accordingly, monetary costs.

The substantiation of technical feasibility, environmental safety and energy efficiency of GPV as a new type of space transport allows proving the possibilities (technical, environmental and energy) for the practical implementation of the space industrial vector of development. In order to fundamentally argue the chosen vector of industrialization of space using GPV, the author proposes to justify effective demand by calculating the costs of producing space goods and services, which should be fundamentally smaller, and also evaluate their quality, which should be fundamentally better, while the goods themselves must have new unique properties.

The economy of industrial space reliably and monopolistically has a number of competitive advantages. This is a completely different economic paradigm, which knows no boundaries, because the GPV is a wide-open door to the space storerooms with unlimited resources in the form of energy, raw materials and space. This operation in the specific technological conditions of the space environment predetermines a fundamentally new and substantially more efficient technological mode of the industries of the real (material) sector. Being the fruit of the collective efforts of the world community and its elites to eliminate threats from the Earth's technosphere (as is the case with the protection of the ozone layer), the economy of industrial space can be supported in the form of further tightening of environmental standards and, possibly, any trade and tax preferences. All this predetermines the investment appeal of space technologies and the absolute competitive advantage of goods and services produced by the space industry.

The scenario of moving in the direction of the space vector of space industrialization involves the consistent creation of price-competitive driver industries, namely: geocosmic transport, space solar energy, mining and processing of raw materials, and only then – the development of other industry directions. And these are precisely those industries whose analogues on Earth are the most dangerous in terms of environmental pollution and resource depletion, and therefore must first be transferred to space (or rather, re-created in orbit, and folded on Earth). It is extremely important that the global consortium provides full control over these driver industries, since only in this case the entrepreneurial factor and its inherent commercial allowances will be excluded – this will allow not to undermine the competitiveness of tariffs for space transport services and space electricity, as well as prices for space raw materials.

The basis of industrial space energy can be made up of space solar power plants (SSPP), which are film panels with an area of tens of square kilometers, reflecting the focused sunlight on the receiving device. Part of the solar energy can be converted into electricity for the own needs of the space industry. Another part of the solar energy can be exported to Earth in the form of an energy-intensive laser beam, converted into electricity already on Earth.

The efficiency of SSPP is determined by the high power of the solar flux of 1,366 W/m^2, while on the Earth's surface it does not exceed 100 W/m^2 [4]. Thus, in the case of SSPP, fuel costs reaching 50–70 % of the cost in the case of thermal and nuclear power plants are excluded. The absence of fuel and its combustion products leads to the absence of costs for cleaning or disposal of harmful emissions or for the burial of radioactive waste and spent contaminated equipment. The simplicity of redirecting an energy-intensive beam from space from one receiving device on Earth to another eliminates the cost of trunk transmission of electricity to various territorial consumers, including in hard-to-reach and remote areas. The simplicity of the technology and the low specific consumption of materials by SSPP substantially reduce the specific capital costs and, as a result, depreciation and repair costs are proportionally minimized. The autonomy of the space technological component of SSPP, which does not require maintenance and the presence of human resources, means a significant reduction in labor costs and social contributions.

The cost of SSPP electricity taking into account the costly delivery by rocket carriers is projected up to six times lower than the cost of electricity generated on Earth [5]. However, taking into account (as compared to rocket carriers), a thousandfold reduction in capital costs when delivering SSPP equipment to orbit using GPV, and also realizing that certain operational costs will occur, the cost price of SSPP electricity is projected up to 50–100 times less than the cost price of the electricity generated on Earth.

Low, at the cost level, internal space tariff for electric energy (considering that GPV is a vehicle and an electric consumer) will further reduce the already competitive transport costs of GPV. These tariffs will allow producing equally inexpensive hydrogen fuel from ballast water of GPV, and later from ice mined on asteroids. And already low internal space tariffs for electric energy (for delivery to orbit using GPV) and for hydrogen rocket fuel will allow beginning the development of deep space.

It is not only about launching and servicing a large number of near-earth satellites and their subsequent utilization. It will be possible to send industrial expeditions to asteroids, provide energy-intensive mining and processing of rock, deliver industrial volumes of asteroid raw materials to orbit and export part of the raw materials to Earth. The asteroids that are closest to the Earth (to date, about 800 have already been counted) have been studied in sufficient detail and classified by size and elemental composition. It is known that in the depths of an asteroid with a diameter of 1 km there are about 30 million tons of nickel, 1.5 million tons of cobalt and 7.5 thous. tons of platinum, estimated at trillions of US dollars [6]. The minerals of asteroids and the Moon are characterized not only by their surface occurrence, but also, which is important, by their non-metallic native form. According to the data of the global manufacturer of non-ferrous metals GMK Norilsk Nickel OJSC, the content of useful elements in impregnated (poor) ores is 0.2–1.5 % Ni, 0.3–2.0 % Cu and 2–10 g/t of platinum group metals (PGM), and in rich ores the content still does not exceed 2.0–5.0 % Ni, 0.3–2.0 % Cu and 5–100 g/t PGM. At the same time, the difference in the costs of mining and enrichment, for example, of 1 ton of nickel of poor (impregnated) and rich ores differs by about five times [7]. That is, the difference in costs is correlated with the difference in the concentration of this useful element. Consequently, the space cost of extraction of native metals is guaranteed to be less than that of the Earth, and proportionally to the concentration difference, which reaches several tens of times due to the lack of ore concentration.

The priority capacity building of space energy is a strategic task and the material basis of the vector of space industrialization. By the example of the electricity consumption structure in Russia in 2017, it can be seen that households occupy only 14.3 %, the rest of electricity consumption falls on the technosphere, including mining – 12.4 %; processing industries – 29.2 %; energy sector – 11.7 %; transport and communications – 8.5 %; agriculture – 1.4 %; construction – 1.2 %; other consumption – 16 % [8]. At the first stages, the newly created space energy will be the first to enter into a competitive confrontation with the electric power of the Earth, primarily hydrocarbon one, and will also energetically ensure the development of its own space primary industry, which will support the competitive confrontation in the markets of the mining and processing industries of the technosphere. As the Earth's technosphere decreases and the capacities of the space industry increase, the space electric power industry will retain its workload, only switching from exporting electricity to Earth to supplying the newly created capacities of the space industry.

As for the creation of consumer industries of the industrial space economy, which are much less energy-intensive, spend not so many resources and are not so harmful for the biosphere, but are much more complex in technological processes, their goods and services in the space environment will differ favorably in many times with their lower cost price. This is facilitated by the specific conditions of the space environment – weightlessness, vacuum and purity (no inclusions), high and low temperature environments, the reconstruction of which does not require spending enormous funds that fundamentally expand technological capabilities and significantly reduce the cost of production and improve quality, allowing to produce many completely new materials with unique properties.

For example, in space, secondary forces dominate (in particular, surface tension) and any alloyed material in weightless conditions automatically takes the form of a sphere, after which it can be given the desired shape by an insignificant effect of external forces created in an acoustic, electromagnetic or electrostatic field. In addition, the modern level of 3D technology allows not only to automate and robotize the production of almost any product, but also to ensure the composition of materials or the finishing quality of surfaces. These technologies (by virtue of the principles of shaping and digital control described) allow for the remote retooling of production programs, which eliminates downtime and the cost of manufacturing and reconfiguring equipment, expanding the product line without additional logistic costs. In addition, space production is distinguished by the unified form factors of the raw materials used – liquid, plastic, wire or powder – this is a smaller number of technological processing of raw materials and lower logistics costs. Finally, these technologies significantly reduce and, in some cases, eliminate technological waste, and if it occurs, the costs of its disposal in space conditions are also minimal.

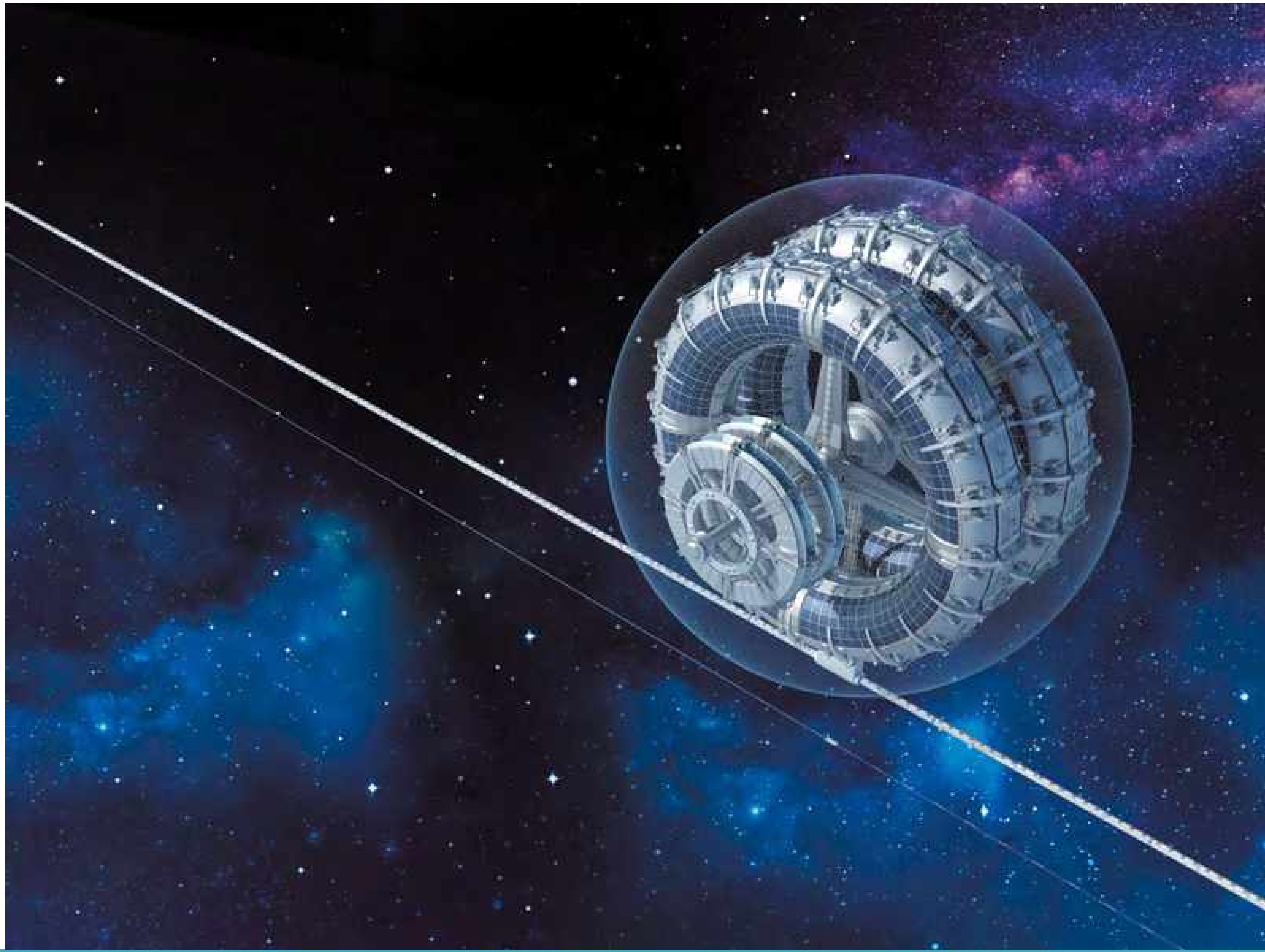
Complete robotization and the absence of the human factor (apart from minimizing the payroll and reducing direct costs) can significantly expand technological capabilities through the use of possibly more efficient, but hazardous or poisonous substances. In the absence of production personnel, there is also no need to solve a number of over-production and non-production very costly tasks, such as: ergonomics and safety of working conditions, measures to prevent victims in case of a risk of industrial accidents, to maintain the accompanying work of any social infrastructure personnel.

The qualitative competitive advantages of goods and services of industrial space are also associated with specific environmental conditions, respectively, the relatively worse quality of earth goods and services or the high costs of its provision are due to the lack of physical conditions on Earth.

Gravity is a major disadvantage of terrestrial production conditions, since most solid materials undergo a stage of softening or melting during their creation or processing, and where gravity exists, the plastic or liquid material must be held by the walls of the processing vessel, and it is also the cause of all defects in the material structure. In addition, gravity causes convective currents along temperature gradients in fluid layers, which are chaotic in nature, which leads to undesirable structural heterogeneity of materials. If the fluid consists of two or more parts, then gravity, due to the difference in the physical properties of materials, contributes to their separation, not allowing to obtain a homogeneous structure. The main advantage of composite materials is that they are composed of substances, the physical and chemical, mechanical and other properties of which complement each other. Under zero gravity conditions in space, this does not occur, so the materials or their composites produced in space are homogeneous, have no structural defects, and have substantially better quality indicators.

Another major strength of the physical conditions of space for production are the purity and rarefaction of the atmosphere, which cannot be obtained on Earth, because in relatively small volumes of artificial vacuum the effect of accumulation of sputtered materials and impurities on the developed surface of the vacuum equipment and their subsequent uncontrolled re-evaporation is inevitable.

Another advantage of the physical conditions of space for production is the possibility of rapid cooling to ultra-low temperatures, which (especially in combination with the presence of a high vacuum) opens up new ways for technologists to control the phase composition of the materials produced, the degree of their homogeneity, the nature and density of crystal lattice defects.



Weightlessness, vacuum, purity, cryogenic temperatures and other factors open up the widest technological prospects not only for metallurgy, but also for the production of nonmetallic types of structural materials and components, including organic and biologically active substances, which broadens the prospects for pharmaceuticals and bioengineering. In turn, new materials with unique properties are a technological breakthrough in related industries.

The process of targeted transfer of space technology to other industries began at the end of the last century. This has already led to a significant increase in the level and quality of life of earthlings and to the return of investments in space programs in the form of direct or indirect economic effect. According to Bryce Space and Technology, in 2017, the space industry showed a weak growth of 1 % [9]. At the same time, experts from Morgan Stanley, Goldman Sachs, Bank of America and Merrill Lynch predict that by 2040, the space industry will reach $1.1–2.7 trillion, i.e., will increase by 2.8–7.7 times, respectively, and explain this by the expectation of fundamental breakthroughs [10]. They mean: an increase in the number of market participants and the rocket launches they make; a project of global Internet coverage of the Earth's surface; projects of space solar power plants; mining projects on asteroids, on the Moon and other celestial bodies; space debris collection projects and many others, recently regularly announced, mainly by US companies. Law H.R.2262 adopted by the US Congress in November 2015, encouraging the commercial development and use of asteroid resources and recognizing the right of US citizens to own asteroid resources that they extract can be considered as confirmation of the seriousness of the announced intentions.

However, when the general business community becomes aware of a new type of space transport (GPV of engineer A. Unitsky) with the price of cargo delivery into orbit being thousands of times less than that laid down in the business plans of breakthrough space projects, and almost free delivery back to the Earth, it can be stated with a high degree of probability: the world will survive a "space fever".

Scenario development of the space industrialization vector suggests that with the transition to self-sufficiency with "free" and unlimited space resources, the economy of the industrial space will win a convincing victory over the Earth's technosphere. As a result, only those branches of the technosphere that either do not have a detrimental effect on the biosphere, or are sufficiently effective and slightly deplete natural resources, or those without which humanity is difficult to manage, will remain on the Blue Planet. In the future, the possession of space resources will allow mankind to restore the original appearance of earthly landscapes and to rebuild a new urban way of life harmonizing with nature, which is possible today thanks to a land-based string transport, also developed by engineer A. Unitsky.

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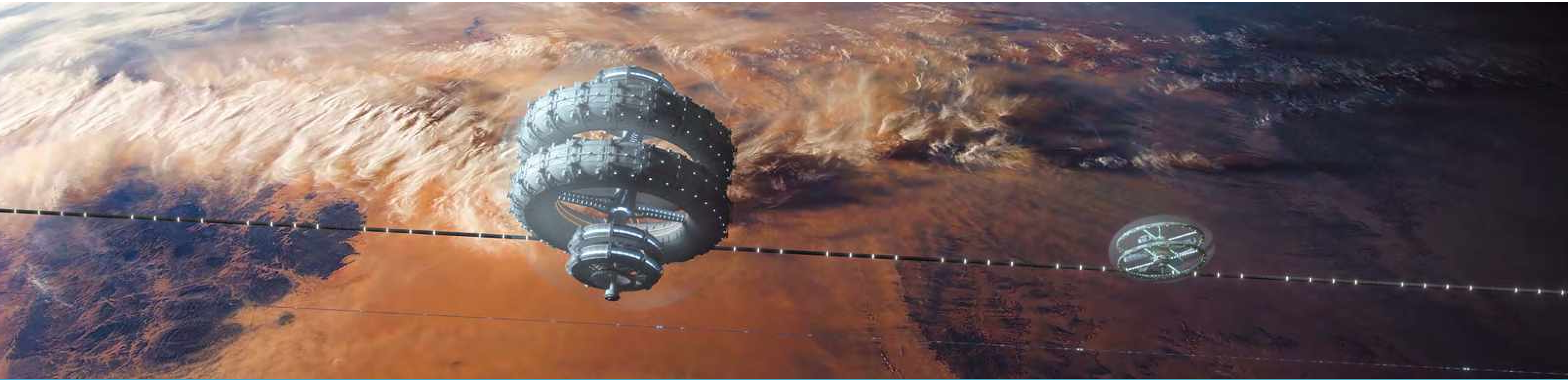

UDC 341.018

Principles and forms of international cooperation in implementation of the SpaceWay program

A. KAZAKEVICH (Minsk)

The article is dedicated to study of the international legal principles and forms of cooperation in the context of the countries' participation in large-scale international projects, namely within the framework of implementation of the only possible way to save the biosphere by moving the industry out of the planet Earth using the Unitsky's General Planetary Vehicle (GPV, SpaceWay project). As part of the study, the analysis of the basic principles of international law and forms of international cooperation was conducted, the prospect of applying the existing principles and forms during implementation of the SpaceWay project was considered, the impact of the project implementation on development of the international relations, strengthening of the principles of international law and expanding of international cooperation were additionally analyzed.

Keywords:
international legal principles, forms of cooperation, SpaceWay, General Planetary Vehicle (GPV).

The SpaceWay program, involving construction of the Unitsky's General Planetary Vehicle (GPV), is undoubtedly a planetary, worldwide project [1, 2], which implies direct and indirect participation of a large number of subjects of the international law. Such participation generates complex multi-level relationships between the subjects, which follow specific rules and are expressed in certain forms. This article offers to consider the following issues:

1) principles of the international law as the most common fundamental norms (rules), in compliance with which the subjects of international relations act, the possibility of their application to the relations arising between the participants of the SpaceWay project, and the possible influence of the SpaceWay program on the specified principles;

2) existing forms of the international cooperation as the basis for building relationships between the participants of the program under consideration, the compliance of such forms with the needs of the project, their applicability at different stages of the GPV life cycle.

The doctrine of the international law identifies 10 universal principles [3], but in this article we will focus only on six of them, which can affect implementation of the SpaceWay project and, vice versa, which the SpaceWay project can influence during its implementation or operation.

The principle of non-use of force and threat of force

According to Cl. 4 Art. 2 of the UN Charter "All Members of the United Nations shall refrain in their international relations from the threat or use of force either against the territorial integrity or political independence of any state, or in any other way incompatible with the goals of the United Nations" [4].

As for implementation of the SpaceWay program, the principle of non-use of force and threat of force will be expressed in the following. The implementation of such a large-scale project seems possible only with the participation of the most (if not all) nations of the planet. The participation of such a large number of sovereign subjects of the international law is possible only in case of their legal equality and absence of coercion in any form.

On the other hand, involvement of a large number of states in implementation of the planetary scale project necessary for the entire humanity will contribute to their consolidation, dispute settlement or at least smoothing of the existing conflicts and establishment of the power balance. Thus, to follow a common, globally significant goal will be a powerful uniting factor in development of the international relations.

The principle of peaceful settlement of international disputes

According to Cl. 3 Art. 2 of the UN Charter "All Members of the United Nations shall settle their international disputes by peaceful means in such a way as not to endanger international peace and security and justice" [4].

This principle of the international law has a huge impact on the process of implementing the SpaceWay project, since a large number of fairly different subjects and the complexity of their relationship will obviously give rise to a significant number of international disputes and mutual claims of participants. However, it should be noted that in this situation the settlement of such disputes for the above reasons is possible only by peaceful means, without the use of force or threat of force.

In its turn, the SpaceWay project is able to influence strengthening of the principle of settling international disputes by peaceful means. As noted above, the pursuit of a common, globally significant goal can unite different subjects of the international law, which undoubtedly will send settlement of all international disputes to a peaceful course. After the project is implemented, the number of international conflicts should be minimized, because, firstly, all efforts of the humankind will be focused in a different direction: the non-rocket exploration of space and restoration of the Earth's biosphere; and secondly, many problems (territorial, resource, financial) will remain in the past after the space exploration.

The principle of non-Intervention (non-interference in domestic affairs)

The international law, by its nature, does not regulate the issues within the internal competence of the states. According to the legal references, the intervention is understood as "any measures by means of which the states or international organizations try to prevent the subject of the international law from settling its internal affairs" [3].

Each state has the right to determine its own political, financial, economic, social and cultural system independently without any intervention.

At first sight, it may seem that the above principle is not related to implementation of the SpaceWay project, since it concerns only the internal affairs of each state individually, but a detailed review can reveal their direct connection. Thus, each state will independently decide on its participation in the project under consideration, and since we are talking about absence of coercion and threats to productive cooperation, such decision cannot be imposed from the outside and should be made without interfering with internal decision-making mechanisms in each individual state or organization. Each subject of the international law should independently realize the need for everyone to participate in construction of the GPV as the only possible way to preserve the biosphere.

The principle of duty to cooperate

Guided by the UN Charter, the states are obliged "to ensure international cooperation in settling international issues of economic, social, cultural and humanitarian nature", as well as "to maintain the international peace and security and, to this end, take effective collective measures" [4].

The principle of cooperation is the basic principle of the international law, which is recognized by an absolute majority of scientists [5]. Considering what was said earlier, the connection of this principle with the SpaceWay project is obvious. On the one hand, since construction and commissioning of the GPV are able to solve major today's human problems, in accordance with the UN Charter, the states are obliged to cooperate in this sphere (provided, of course, that the SpaceWay project will be recognized by the international community as the means of solving such problems). On the other hand, implementation of such a large-scale project is impossible without cooperation of many states in this sphere.

The principle of sovereign equality

Cl. 1 Art. 2 of the UN Charter provides that "the organization is based on the principle of sovereign equality of all its Members" [4]. The principle of sovereign equality implies that every state is obliged to respect the sovereignty of other states, i.e. their right to exercise legislative, executive and judicial power on its territory without anyone's intervention, to independently determine its domestic and foreign policy.

As a matter of fact, the states differ in their level of economic, social, political and other development, but for normal functioning of the current system of international relations, it is necessary for differing subjects to have fundamentally the same rights and duties: this is the main purpose of the principle of sovereign equality of the states.

The influence of this principle on the SpaceWay project can be characterized as follows. The most likely form of international cooperation in implementation of the SpaceWay program is an international treaty (see below). In its turn, the nature of the contract itself involves participation of equal subjects which assume certain obligations by expressing their free will.

In addition, the SpaceWay project will strengthen the principle of the sovereign equality of states, since each entity involved in the project will receive certain levers of influence, which could become the means of achieving not only formal, but also actual equality in the international relations.

The principle of faithful fulfillment of obligations under international law

The principle under consideration is determined in Cl. 2 Art. 2 of the UN Charter stating that: "All Members of the United Nations conscientiously fulfill their obligations under this Charter to ensure that all of them together have the rights and benefits arising from membership of the Members of the Organization" [4]. This principle is also one of the fundamental international legal customs of pacta sunt servanda ("treaties must be kept").

Considering this principle in the context of its connection with the SpaceWay project implementation, one should consider the following in more detail. Construction and commissioning of the GPV is possible only with the participation of a large number of equal subjects of the international law, which actions, rights and obligations are most likely to be governed by an international treaty. Therefore, the principle of faithful fulfillment of the obligations is fundamental in this regard. At the same time, one should pay attention to the opposite situation: implementation of the SpaceWay project will strengthen this principle, since, acting as a project aimed at saving the humankind, the early completion of the GPV construction will become a significant incentive for the parties to fulfill their obligations in good faith.

In legal references, the following notion for the form of cooperation is offered: "Under cooperation forms we understand the framework within which the cooperation between the states takes place" [6]. However, for the purpose of this article, we use a broader definition. The international legal form of states cooperation is a joint bilateral or multilateral activity of the states carried out on the basis of international agreements in political, economic, scientific, technical, legal and other spheres aimed at maintaining the international peace and security and promoting the economic stability and progress [7].

There are two main forms of international cooperation discussed in the reference literature: conclusion of the international treaties and participation in the international organizations [3]. Let us consider them in relation to implementation of the SpaceWay program. According to the author, the most likely form of international cooperation in implementation of the SpaceWay project, at least at the initial stage, is the conclusion of an international treaty.

An international treaty is a clearly expressed legal act concluded between two or more legal entities, which regulates relations between the parties by indicating their rights and obligations in various spheres [3]. The treaties may provide for creation of the joint working groups, exchange of specialists, use of the joint educational programs. An international treaty may create a new international institutional structure (an association, organization). The treaty may be a framework treaty, providing for the possibility of further cooperation through conclusion of additional agreements [7].

As it can be seen from the above conditions of an international treaty, its scope of application is so diverse that it allows to foresee all possible options for the parties to implement the SpaceWay project.

Cooperation within the framework of multilateral international treaties is seen as the most effective way to implement such a large-scale space project, which implementation will involve many states. This is due to the fact that within the framework of this form of cooperation, the interaction of the states is limited only by the norms of the international law and the will of the interested states to cooperate the participants are not bound by the obligatory formalized procedures and the need to receive the support of all states.

In a similar way, a high degree of adaptability of cooperation is achieved, the interaction of the states is carried out promptly, bypassing the procedural constraints of certain institutional structures; the states conclude only such international legal acts that are necessary for performance of the current tasks, at the same time preserving the possibility of their prompt revision or amendment.

The second form of international cooperation under consideration is participation in the international organizations. Cooperation may take place within the framework of the world universal international organizations. Cooperation may also be realized within the framework of the regional organizations.

With regard to the sphere under consideration, it can be stated that participation in the international organizations is a higher level of development of the SpaceWay project, which will be possible when many subjects of the international law will be interested in development of the program.

The following assumption seems reasonable that due to the location of the GPV, a regional organization can be created consisting of the countries on which territory the geocosmic vehicle will be located.

With all the advantages of such a form of cooperation as the international treaty, it should be noted that participation in the international organization is still more binding for the subject of the international law, and therefore, at a certain stage of the SpaceWay project life cycle, it is the creation of a regional and/or global international organization that will become a reasonable necessity.

The analysis performed allows us to conclude that the relationship between the subjects of the international law within the scope of their participation in the SpaceWay program fully fits into the framework established by the existing principles of the international law. At the same time, one can say with confidence that implementation of the SpaceWay project will contribute to strengthening and strict observance of these principles by all the participants of the international relations.

The forms of international cooperation considered in this article correspond to all the essential conditions for implementation of the SpaceWay project at each stage. In particular, the international treaty is the most appropriate form of cooperation at the GPV design and construction stages, and at the stage of operation it is necessary to create the international organization.

However, the above does not exclude that within the process of participation of the subjects in implementation of the globally significant large-scale project, new principles of relationships and forms of international cooperation will be developed.

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UDC 004.45

Readiness of modern digital technologies for the development and manufacturing of astroengineering structures

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This article considers modern technologies that are applicable at all stages of creation of the astroengineering structures from idea to production-scale. The article contains description of the tools necessary for solving of possible problems, among which the most notable are: design modules, behavior modeling systems, methods of system engineering, management of multiphysical and cyberphysical objects and systems, use of a multidisciplinary approach and a digital twin of the product. The last tool paid special attention: in the paper is researched the preparation of multi-threaded production, its balancing and logistics, the calculation and optimization of supply chains for the supply of raw materials. In addition, an overview of advanced technologies applicable to the construction of such structures is given: additive technologies, generative design, technologies for optimization of design solutions.

Keywords:
astroengineering structures, Industry 4.0, additive technologies, digitalization, digital product twins, digital production twins, simulation modeling.

During the last decade in the world has been observed a new wave of space, accompanied not only with expanding the boundaries of space activities, but also by the emerging transition to new space technologies aimed at increasing its efficiency and the safety of humanity. In order to achieve sustainable development on Earth and in space, it is necessary to reach a new level of space exploration through the creation and implementation of a superglobal strategy. The goal of any project included in such a strategy will be the survival of civilization and its development, the protection of the Earth and the formation of cosmic humanity.

There is a significant potential for the formation of a new technological structure by means of transition to environmentally friendly technologies and projects, many of which have been developed for a long time and are ready for practical implementation [1]. One of such technologies, related to the category of non-rocket flights into space, is the GPV – General Planetary Vehicle. It main purpose is to launch cargo on different circular equatorial orbits using the only possible technical solution implementing environmentally friendly clean method of access into space – in process of functioning are absent any significant interactions with the environment (energetic, mechanical, chemical and other types) [2]. As a geocosmic vehicle, GVP is a giant astroengineering construction in the form of a stable self-supporting structure, the building of which will require a fusion of the most advanced ideas and technologies that are used by humankind today, as well as all of its accumulated knowledge and skills in space exploration.

Will modern design and production tools be enough to create a GVP? The purpose of this article is to find the answer to the question: "Are the innovative technologies ready for the implementation of planetary-scale astroengineering structures?". The research on the topic requires an in-depth study of not only the design and production tools, but also the necessary competencies of engineers and workers, as well as their level of interaction at the confluence of different disciplines.

It is assumed that in each element of GVP (Equatorial Linear City (ELC), including launch pad for GPV, Industrial Space Necklace "Orbit" (ISN "Orbit"); biosphere EcoCosmoHouses (ECH)) will be used almost all known systems: mechanical, control, communications, life support, security, power, energy, hydraulic, pneumatic, biological, computer and many others.

The creation of astroengineering structures is an ambitious task for humanity, requiring the unification of almost all modern design and production tools, taking into account the entire life cycle of such systems. It is necessary to develop the understanding of the current approaches of design, production and development of new techniques with more systematic, transparency and digital data connectivity. In addition, a large number of specialists involved in different disciplines and different countries should be united, and should be created conditions for their joint activities. To accomplish this task, it is also necessary to use computational powers sufficient for conducting virtual experiments on the elements of GPC and its subsystems.

The construction of such large-scale astroengineering structures will require the development of an integrated system architecture with high level of functional safety that takes into account all subsystems, parameters and connections of hundreds of thousands of factors between them. For example, a modern passenger car has about 300,000 requirements, separated by specifications for different systems and subsystems. Moreover, it would be necessary to create conditions for converting uncertainty in requirements, solutions and system architectures into understandable tasks and precise parameters that affect the behaviour of different systems in different situations. In order to get that done, it is necessary to improve the approaches of system engineering of simulations and simulation modeling. Digital twins of products and systems that are part of the architecture of astroengineering structures should have the quality that ensures accuracy and detail 1:1 for subsequent production. In addition to multiple calculations, a large number of virtual experiments and validations will

be required when developing astroengineering structures and their systems, for these purposes will be used practically all available software and hardware capabilities of digital. The increased number of virtual experiments and simulations (as compared with typical facilities) is due to the fact that carrying out tests of life-size prototypes of different systems and subsystems can either be difficult or impossible.

Due to the global nature of the project on development and construction of astroengineering structures, its implementation will require precise coordination of the activities of a large number of suppliers and manufacturers around the world, companies involved in the subsequent assembly. All this will lead to the need to conduct many processes in parallel: development, production, construction. At the same time, a significant role will be played by the complex optimization of design, technological and design solutions: according to weight, energy, strength, materials science, operational, cost and other technical and economic characteristics.

The global process of computerization, digital technologies, the development of cyber-physical systems embedded in the means of production and in the various components of the products in order to automate and link development, production and operation have allow us to talk today about a breakthrough in the creation of a number of products. At the same time, there is an increase in the complexity and quality of new products, as well as the acceleration of their release and market launch. The combination of digital and cybernetic technologies in the methods of development and production is a tool of the fourth industrial revolution (Industry 4.0). The combination of scientific disciplines, technologies and innovations as a result of their interaction becomes possible mostly due to the constant increase in the speed of transmission and processing of information, usage of digital tools for joint and remote activities. Already today, companies and countries take part in collective innovations, creating environments for joint operation at the intersection of technologies and accelerating the introduction of products to markets in all areas. At the same time, the opportunities are provided for continuous improvement and updating of both development methods and production, which leads to the birth of completely new products (for example, when combining additive technologies, material engineering, synthetic biology) [3].

Digital platforms for product lifecycle management (PLM) – complex digital system made up of subsystems with individual tools that affect different aspects of development, design, verification solutions, production, operation, disposal, optimization of engineering solutions at all stages of the life cycle. This system interacts with the unified current data at the current time, which allows different participants of the product creation to see all past changes in related areas, collisions and eliminate errors before the start of production.

Today's PLM-platform can include several thousand special modules. Let us specify the main modules for construction of astroengineering structures:

- **CAD** – computer-aided automated design tools, 3D-models or 2D-drawing of physical components;
- **CAE** – computer-aided tools for automation of the engineering calculations, analysis and simulation of the physical processes;
- **CAM** – tools for technological preparation of the production of items, provide automation of programming and management of the numerically controlled equipment or flexible automated production systems;
- **CAPP** – tools for automation of the technological processes are used at the joints of CAD and CAM systems;
- **PM** – project management systems;
- **PDM** – system for product data management;
- **WMS** – warehouse management system;
- **CMMS** – system for service maintenance management;
- **CSRM** – management of the interactions with the clients and suppliers;
- **MES** – special applied software for solution of the tasks related to synchronization, coordination, analysis and optimization of the output of productions within the frameworks of any production;
- **MOM** – production process management (operations);
- **ERP** – planning of the resources of the enterprise;
- **BIM** – information modeling (or model) of a building;
- **MBSE** – model-centered approach to systems engineering;
- **MDB** – non-drawing technology containing annotations and markup not in a 2D-drawing, but immediately on a 3D-model
- **VR, AR** – technologies of additional and augmented reality, creating a virtual scene based on a 3D-layout and dynamic data and using special glasses that simulate stereoscopic behaviour for a person. AR allows you to complement the picture from the real world with elements of virtualization;
- **IIoT** – Industrial Internet of Things, the technology of creating cyber-physical objects by embedding computers into actuators, individual devices and entire industrial lines, allowing to build all the elements into a single system suitable for both production purposes and operation. One of the developmental branches of IIoT is the development of crypto-anchors;
- **Digital twin, digital Shadow** – creation of a digital twin of the product and a digital shadow of the manufacturing process, simulation of all stages of production, taking into account the behaviour of equipment and equipment [4].

Today, there are three global manufacturers of the platforms Industry 4.0 on the world market, which allow uniting an unlimited number of participants to build any products and systems: Dassault Systèmes offering leading in the industry applications on the basis of 3DExperience platform; Siemens – PLM offers its own solutions on the basis of Siemens PLM-platform; PTC, Inc – on the basis of PTC-platform.

The complex of the described PLM-modules in a single bundle allows you to implement high-quality digital twins both at the stages of designing and product development, and at the stage of early tests. Only PLM platforms and modules included in them (high-level CAD, for example, CATIA from Dassault Systèmes), allow to create digital twins of such objects of increased complexity as GPV or ISN "Orbit" in natural scale with engineering accuracy along the whole length of the objects without abruption (for example for GPV – more 40,000 km). In one digital layout in 3D should be designed: terrain relief, foundations, supports, design of the overpass, GPV. In addition, the PLM-platform allows you to combine in the simultaneous development of the necessary number of engineers and applied specialists, while centrally managing all related documentation and keeping all versions and revisions of changes in conjunction with the project objectives. Such an approach makes it possible to identify all inconsistencies and deviations of different projected areas and systems. Today there is an experience of creating digital twins with more than a few million items (for example, Harmony of the Seas, an Oasis class cruise ship, consists of about 50,000,000 parts, was modeled in PLM 3DExperience).

One more serious problem that has to be solved in the during creation of astroengineering structures is to reduce to zero the design and production errors, since even minor errors associated with the creation of complex objects can lead to serious consequences. Therefore, an important role will be played by an approach known as system engineering. Traditional systems engineering [5], although it is good enough, leaves a room for error. One example of the "collapse of the classical approach" is the NASA Mars Climate Orbiter crash (launched on December 11, 1998), which after nine months of flight crashed on the surface of Mars due to the soft ware being written by two different groups of developers using different units of measurements: newton and pound-force [6].

Figure 1 demonstrates an example of product quality differences manufactured with usage of the "old" (document based) and advanced (data-centered) approach to system engineering MBSE (based on combination of the digital technologies).

The essence of the advanced model-centered approach lies in a comprehensive solution linking the digital twin of the product in 3D with the functional model – FDMU, RFLP [7]. The simulation tests, simulation modeling in virtual space, analysis at the level of expert systems using the generation of anomalies, system analysis of impacts, system analysis

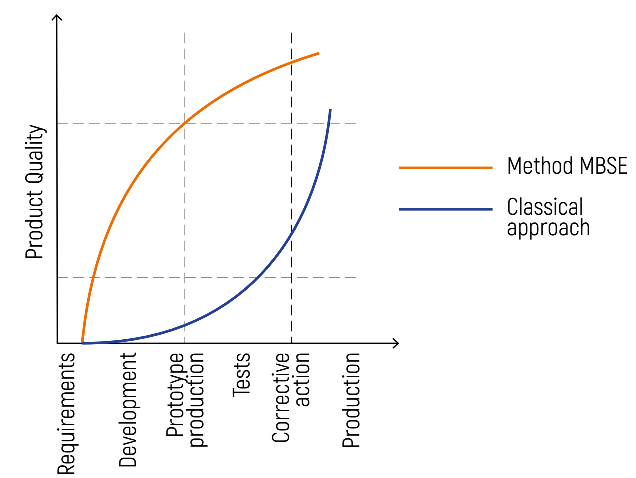

Figure 1 – Standard and advanced approaches to system engineering

of intersections and system conflicts are used for early checks of the correctness of behaviour. The obtained results allow to eliminate errors, carry out multidisciplinary optimization of the item, product or the entire system, confirm satisfaction with all the requirements. This approach significantly improves the processing of errors and the maturity of the product at the pre-production stages, reduces the influence of the so-called "human factor".

MBSE methods, in addition to improving the quality of the created product and reducing the number of errors, can be used both in the design of astroengineering structures for the development of systems and their intersections, and for communication with existing systems. For example, for the synchronous joint operation of the GPV control systems with the air traffic control systems and with the monitoring systems of submarines and surface ships throughout the Earth. These methods are already widely used in the development of aviation and space systems and programs.

Simulation modeling is an important part of digital systems engineering. It is a research method in which the system under study is replaced with a model that describes the real system with high accuracy (the model constructed reflects the processes as they would have passed in reality, taking into account the nonideality of real processes). Such a model can be "play back" in time both for one test and for a given set, as a result allowing to receive fairly stable statistics. Today, the convergence of results in the virtual and real worlds can reach 96 %. The achievement of a high approximation of modeling is Zero-prototyping – safety certification without real crash tests (used by BMW AG, Honda Motor Co.). Usage of PLM-tools allows to implement an integrated approach to studying the behavior of the product and systems under development. In particular, the digital twin in 3D with all systems (mechanical, hydraulics, pneumatics, electronics, etc.) is subjected to simulation simulations, including interaction with different media and materials in dynamics. The use of VR may allow a deeper and more comprehensive study of the behavior of components and assemblies of the product being created, be it a passenger gondola or elements of linear engine of GPV.

The next level of simulation includes the connection of digital models of the physical environment and actuators with their 3D-simulator to control computers (controllers) operating with digital data. Thus, Tesla, BMW, Renault and other companies conduct debugging of control systems in virtual space using real controllers, finding out the best algorithms and eliminating gross errors for systems such as AEBS, mechatronics, electrical power plants at an early stage. After the training is conducted a series of finishing works with actuating mechanism under the conditions of a real experiment. The same principle, allows to train neural networks in the virtual space and then transfer the results to "iron". A similar level of simulation can be used in the flight control center (MCC) to simulate the control of a GPV in different situations, taking into account thousands of events at any point and with any system, implementing different algorithms of behavior.

Simulation modeling plays very important role in the development of astroengineering structures, as it allows, in conjunction with digital twins and system engineering, to very accurately debug methods of control for systems, in conjunction with digital actuators, to imitate the ways of functioning of GPV systems on Earth, creating thousands of take-off and landing options, identifying the weaknesses of real industrial controllers controlling an GPV imitating various events and improving the ways of behavior and control of GPC on a software-hardware model. Moreover, it is possible to approximate on Earth the results and develop different scenarios for the behavior of ECH systems in space, bundles of life support systems and security, in advance preparing ECHs for various regular and abnormal events.

All the above-described tools of the Industry 4.0 concept (CAD, CAE, CAM, WMS, MES, MBSE, simulation modeling, etc.) also find their application for production and construction purposes.

Digital production – IIoT, AR, Big data (big data), digital shadow and planning systems allow to calculate power balancing taking into account the separation of production sites. Such control systems will be in demand in the preparation of uniform interconnected schedules for the manufacture and construction of astroengineering structures, primarily GPV, as this will require simultaneous coordinated actions throughout the entire creation of an object of a large number of manufacturing factories and construction organizations around the world.

If we consider end-to-end processes from development to production, design and construction, we will see that the quality of the resulting product depends on the maturity of the process at all stages of the life cycle. In the classic version today there are five such levels (Table).

When building astroengineering structures, the most important task is to increase the maturity of processes to the fifth level (CMMI classification of the ISACA association) and create conditions for the formation of a level higher than the fifth (5+), which in turn will require increasing the digital connectivity of the system elements, qualifications and level of interaction of employees.

When implementing the tasks of industrializing space and building astro-engineering structures, it is also worth noting the important role of additive technologies and generative design [8]. They allow to reduce the time of production of GPV elements, to optimize the mass-dimensional characteristics of elements of ISN "Orbit", to use space materials (minerals from asteroids, space debris), to facilitate the production of necessary tools and parts without loss of strength properties.

All the above technologies are a powerful engine of progress in almost all areas of civilization, contribute to accelerating the process of diffusion of technologies and innovations, which leads to their accelerated creation: from digital collaborative development tools, system engineering, simulation modeling and ending with collaborative innovations.

The results of acceleration of information exchange both between development teams and consumers are the increased competition and the emergence of breakthrough technologies. New approaches are very quickly duplicated and implemented throughout the world, crowding out old business models and products, while there is a drop in the cost of technology, which makes them more accessible and encourages competition in the creation of advanced, more improved means of production and development, as well as more advanced products and systems. For example, the cost of 3D-printing of the same product decreased from $40,000 in 2007 to $100 in 2014, and the cost of 1 kWh of solar energy in 1984 was $30, but reached $0.16 by 2014 [8]. Thus, the diffusion of technology and innovation contributes to cheaper and easier access to technology [9].

In this paper were reviewed modern digital technologies, their potential in case of implementation for building of astroengineering structures with a few examples. Many problems that seemed intractable to engineers and designers 20–30 years ago are no more than tasks of varying degrees of complexity. Restrictions can arise in computing power, but this can be solved by using industrial mainframes with a large number of cores, for example, rented. Digitalization of processes, acceleration of diffusion of technologies and innovations leave no doubt that humankind today has all the capabilities to begin the development and production of astroengineering facilities necessary for the survival and sustainable development of modern earthly technocratic civilization.

Table – Maturity levels of CMMI processes

Value	Level 1 (Basic)	Level 2	Lever 3	Level 4	Level 5 (world leaders)	Level 5+
Name of the level	Starting	Repeated	Standardized	Measurable	Optimizable	
Necessity to redo, %	40	20	10	6	3	< 3
Forecast tolerance, %	From 30 to 100	From 10 to 20	5	3	1	< 1
Reducing the likelihood of defects in the end product	X	1/2X	1/4X	1/10X	1/100X	1/1,000X
Early detection of defects, %	< 30	60	80	90	99	99.9
Performance, %	100	150	200	350	> 400	
Repeated use, %	Insignificant	Insignificant	Accidental	> 30	> 50	

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UDC 001.83

Creative constructivism of the EcoSpace megasystem design and development: engineering creativity with Modern TRIZ – reinventing and perspectives

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The fundamental invariants and concepts of creative engineering thinking are defined as the essential foundations of project pragmatics, aesthetics and philosophy of the EcoSpace megasystem. The implementation of the “Ideal System Maxim” and the “Ideal Change Maxim” creative principles, as well as of the author’s phenomenological definitions of the “Ultimate System” and the “Eternal System” is shown in the “Way”, “Resources” and “Developing System” system invariants development in the megasystem projects. Practical mechanisms for the application of the creative constructivism theory developed by the author of the article in line with the Modern TRIZ direction are proposed for further efficient design and implementation of the EcoSpace megasystem.

Keywords:
EcoSpace, HyperU, GreenWay, EcoEnergy, SkyWay, SpaceWay, system invariants, creative constructivism, creative principles, phenomenological definitions, Modern TRIZ, MTRIZ Academy.

The technocivilization has been created by engineers. For several thousand years, millions of resourceful craftsmen, artisans, masters, engineers and expert scientists have found new ideas, built everything that surrounds us, produced and improved everything that exists in addition to all that has been created by Nature.

At the same time, the technocivilization is now at the deadly point of its uncontrollable growth. The problem consists in inflicting irreparable damage to the nature in many ways. Consumer, greedy, wasteful utilization of the world around us came to the limits beyond which it won't be able to restore itself and provide for the lives of the humans themselves.

Among the most dangerous sources of destruction are transport systems of all kinds, except perhaps the bicycle. All these aspects have been convincingly analyzed in the project substantiations of the need and opportunities for the development of the EcoSpace megasystem, the outstanding concept and constructive ideas of which have been proposed as early as the late 1970s, and first published in the early 1980s by the engineer Anatoli Unitsky [1–4]. The global mission of the EcoSpace megasystem, according to Unitsky, is to prevent the irreversible red line crossing in the destruction of nature and to build a new technocivilization as an ecocivilization that opens up the prospects for unlimited harmonious development of humanity.

Thus, an important task is to increase the efficiency of the EcoSpace systems and components design and implementation. Design efficiency includes the acceleration and quality assurance of design solutions. Creating efficient solutions requires developers' and managers' special abilities in creative design. However, educational institutions have no programs and methods forming professional skills of efficient ideas generation, especially in complex project situations with sharp contradictions between requirements and resources available to achieve project goals.

The required quality, speed and reliability of training specialists in inventive systemically organized design thinking are provided, in aggregate, by the Modern TRIZ (MTRIZ) educational methodology and technology developed at the MTRIZ Academy founded by the author in the late 1990s in Berlin, Germany. Education and training programs on the basics of MTRIZ [5–12] are essential and irreplaceable for project and production activities when creating the EcoSpace megasystem for all specialists, including top-level managers.

The author has been sharing and supporting the ideas of the engineer Unitsky for almost 25 years, and also reveals in his works the EcoSpace megasystem's creative space through MTRIZ-modeling [6–12]. For the first time, at a new qualitative level, a generalization of EcoSpace creative concepts, developing this modeling, is formulated in this article.

At the basis of efficient engineering ideas and solutions lies creative design thinking, which is the ability and skill to mentally see the future function, design, or process. And only then the mental vision is formed in a sketch and drawing, in a mathematical model, implemented in a layout, technology and production and, finally, except for recycling, in application and operation.

For the first time in the history of civilization (and in the history of engineering creation), the TRIZ – Theory of Inventive Problem Solving – revealed the design principles and patterns of creative thinking, offered creative tools – methods, models, and examples – for efficient inventive design thinking [13, 14, 15]. Along with engineering knowledge, the knowledge about the creative space of the engineer's thinking arose. The TRIZ principles (yet without this name) were first published in 1956 and 1962 [13, 14] by its founder Genrich Altshuller (1926–1998), and until the mid-1990s the TRIZ evolved under his leadership [15].

By the mid-1990s, the basic MTRIZ principles were formulated in the form of new structures and procedures (extraction, reinventing, Meta-Algorithm of Invention T-R-I-Z, etc.) in order to efficiently master and apply the TRIZ fundamentals. A de facto "constructive language" was created to present information about the process of invention, accumulation and transfer of inventive experience and solutions, the language of communication in multidisciplinary creative teams (Think Tank Teams).

TRIZ methods and models (MTRIZ) during the training explain the process of birth of an idea, and after the training they become thinking navigators for creating efficient ideas in new problem design situations.

EcoSpace megasystem creative ideas can also be efficiently interpreted in the MTRIZ concept system. This interpretation will help developers understand to more deeply the creative constructivism that constitutes the creative core of the engineering and social transformations being developed in EcoSpace projects. For the sake of brevity, we will consider examples on two key EcoSpace systems – SkyWay and SpaceWay (although, undoubtedly, all EcoSpace projects have outstanding properties and characteristics and correspond to the models and generalizations being considered).

The fundamental metaphorical TRIZ-principle, which sets the vector of development and evolution of systems, is, in the author's interpretation, the Ideal System Maxim: there is a function, but there is "no" system implementing it. Two creative trend aspects are present here: 1) there is no habitual system for obtaining the desired function; 2) the function is created by other (surrounding) systems, or its implementation has moved to another level – higher or lower one. The value of the metaphor is to eliminate the retarding stereotype of habitual thinking, to set an "impossible" goal. Let's reveal (extract) internal creative "springs" of the basic string concept – SkyWay.

What are the development limitations of usual roads? They are not straight, they are cumbersome in design, energy- and resource-intensive, environmentally unfriendly, and therefore costly for humanity. As a result, they are simply "slow" and have no development prospects in principle (they stopped in development). All known roads are like that, from a rural earthy track to a super modern maglev-complex. Could a similar "road" be built so that all these defects would disappear?

It was this "ideal road", "ideal system" that was invented by A.E. Unitsky in the form of a string concept underlying SkyWay projects.

Five technological revolutions are the markers of the "Road" technical system evolution increasing speed and cargo efficiency:

1st revolution (6,000 years ago, the Sumerian state in Mesopotamia): the invention of the wheel – wooden, then iron, and so on;

2nd revolution (5,000 years ago, Egypt; 4,000 years ago, Europe): the invention of the pair "wheel – artificial road" (wooden, stone);

3rd revolution (500 years ago, the mines of England, Ireland, Russia): the invention of the pair "cast iron wheel – cast iron rail";

4th revolution (160 years ago, Robert Thomson): the invention of the pair "pneumatic wheel – road" (earthen, stone, concrete, etc.);

5th revolution (30 years ago – end of the 1970s, Anatoli Unitsky): the invention of the pair "steel wheel – steel string rail".

A.E. Unitsky invented a fundamentally new road that is elevated above the ground (SkyWay), which corresponds to the TRIZ-model "Transition to another dimension" with the ability to link start and arrival points in a straight line (consistent with the models "Change of aggregate state", "Replacing mechanical environment", "Use of composite materials" and "Mediator"). Of course, the old principle of the road to achieve new speeds and throughput no longer exists.

The string-rail (pre-stressed) road is an unexpected, creative, and bold decision possessing, according to TRIZ, outstanding system-forming supereffects: creation of ecological residences for the users of these roads, rational use and purification of the earth, safety and comfort provision.

In the same vein, we can consider A.E. Unitsky's string rail idea "denying" the classic monolithic (solid) rail, even when used in various versions of monorail elevated roads.

The radical problem of the railway pair "steel wheel – steel string rail" consists in the fact that the rail has a small deflection radius, and therefore the railway wheel does not roll along the "perfectly" smooth path, but "gets out of the hole" all the time – out of the bent rail. And so for all a few tens or hundreds of wheels of a heavy train (of concentrated load). Colossal energy is spent on overcoming continuous resistance.

The "smart" string rail (in accordance with the TRIZ-model "Matryoshka") has a core made of tens and hundreds of wires, each stretched as a string, and all together – as a single powerful and perfectly straight "super-string". Here it is – the Ideal System Maxim: there is a function of the "ideal" road, but there is no usual rail. A new "ideal" system rail has been invented.

Now let's pay attention to the fact that there is another creative TRIZ metaphor in the interpretation of MTRIZ – the Ideal Change Maxim: "there are no changes", but there is a result. Another expression for this maxim is: get the result "without changing anything"!

Indeed, outwardly the string rail looks quite "solid" and "monolithic", and therefore it seems that it has not far gone from the classical monolithic rail from the point of view of the deflection radius, since there are no significant changes, except for the external form. However, this is not true: the string rail is a fundamentally new technical system. So there are (almost) no external changes, but there is a new function!

Further, an extremely important system MTRIZ definition "The Ultimate System" is implemented here: the principle of such a system cannot be surpassed, it is the best in the class of all systems of this type. The string road principle cannot be improved on the totality of properties in the class-concept of the "Road" as a mechanical transport system based on the system invariant of this class – the "wheel-rail" pair.

It is important to note that the string rail becomes a system invariant of many transport projects, giving the name to the "string transport systems" class, including SkyWay, HyperU, SpaceWay. Creative design of these systems is covered by the above concepts by analogy with the SkyWay string structure based example. n-turn, all these systems, together with the string concept, are the system invariant core of complex systems and mega-systems GreenWay, EcoEnergy, and EcoSpace.

To develop the study of creative constructivism in EcoSpace systems, let us show the presence of key system and creative concepts, invariants and models in the General Planetary Vehicle (GPV), the idea of which was proposed by the engineer A.E. Unitsky in the late 1970s, and first published in 1982 [1].

First of all, the GPV is an "Ultimate System" – its general idea and physicotechnical principles (acceleration, ascent into near space, maneuvering, being in space, returning to Earth), as well as the principles of structural transformations during operation (telescopic structures, stretching and compression of materials) are one-of-a-kind for self-supporting geocosmic aircraft that do not need a foothold (the "Baron Munchausen" principle). A.E. Unitsky's inventions create a constructive engineering and creative paradigm for the implementation of the aspirations of Russian cosmism and therefore open a new history of the Earth, more precisely, geocosmic civilization.

In the GPV, the Ideal System Maxim is implemented: a linear (tape) rotor, spun in a vacuum channel to a speed exceeding the Earth orbital velocity, acquires the ability to independently rise into space without losing stability – it will be stretched all the time like a ring string.

The presence of the Ideal System Maxim plays an important role in the GPV functioning: the elongation of the circumference of the ring structure (rotors and housing) during and after ascent to a given orbit is a small fraction of its length on the launch structure. So, when the rotor expands from the diameter (broadly speaking) of 12,700 km with a starting circumference of about 40,000 km in length to the orbit diameter, for example, of 13,100 km (i.e., with an orbit "height" of 200 km above the Earth's surface) and the orbit (and hence the rotor) length of 41,100 km, the relative elongation of the rotor will be 2.75 %. From which we can conclude: such elongation can be ensured even at the expense of safe elastic stretching of the rotor material and is quite reliably feasible when using controlled telescopic structures.

The number of instrumental creative models in the GPV idea includes almost all classical TRIZ models. Here we indicate the most important, dominant models in the most simplified illustrative interpretation: "Change in the aggregate state of an object" – stretching and compression of the system components of the structure; "Replacing mechanical environment" – string structure of the main structures; "Dynamization" and "On the contrary" – acceleration for take-off and braking for rotor landing; "Copying" – rotor self-stabilization according to the principle of a spinned lasso; "Periodic action" – possibility of take-off and landing; "Mediator" – the rotor lifts the cargo; "Transition to another dimension" – the rotor spins up in a plane (2D-system), and rises and falls in height (3D-system); "Antiweight" – centripetal forces lift the GPV; "Matryoshka" – the take-off and landing system and the rotor system with the shell are nested structures. Such examples can serve as efficient educational content for EcoSpace designers.

Finally, let us pay attention to the fact that the ideas of EcoSpace complexes exactly correspond to one more MTRIZ system definition the "Eternal System": a human-technical system with a property of unlimited life expectancy due to the ability for self-preservation, self-restoration, self-renewal and self-development. It is easy to see that GreenWay, EcoEnergy, and EcoSpace complexes have all the signs that meet the definition of the "Eternal system".

It should be noted that this does not mean that all previous generations of technical systems "die" (some of them will indeed be dismantled and canceled), most of them will move to another status, while remaining in more appropriate niches of application.

The given examples of the study of system properties arising from A.E. Unitsky's inventive ideas and constituting the creative core of all EcoSpace projects reveal the leading creative concepts of the internal creative space of the EcoSpace megasystem. These concepts relate to the level of engineering philosophy and philosophy of creativity in general. At the same time, we actually carried out the "reinventing" of A.E. Unitsky's ideas at this level.

At the same time, the methods and models of the "instrumental" level can and should contribute to the actual project work. To solve the majority of everyday tasks, methodological knowledge and ability to apply the tools presented in the author's basic books [5–7, 10] are sufficient.

The technology of training and practical work in MTRIZ is based on two methods: extracting (identification and retrieval of efficient creative models from previously made innovations and inventions); reinventing (modeling and reproducing the complete idea creation process in such a way as if this invention was made using TRIZ models). It is this way of presenting knowledge in MTRIZ that makes it possible to model and study the logical structure and procedural components of the invention process.

To standardize the presentation of information, an "ultimate" Meta-Algorithm of Invention T-R-I-Z has been proposed. It is a methodical scheme for describing transformations and reventing results, consisting of four functional stages: Trend (goal setting) - Reduction (formulating contradictions) – Inventing (searching for ideas) – Zooming (analysis of ideas at different scales). The first letters of the names of the stages give the T-R-I-Z abbreviation in the name of the meta-algorithm.

Since all the examples of MTRIZ-modeling and all the processes of creating new solutions follow the T-R-I-Z meta-algorithm, this provides a de facto standardized format for presenting information, which drastically simplifies the learning process, becomes a simple structural format for documenting reinventings and inventings (new solutions), an understandable communication language in multidisciplinary decision-finding groups (Think Tank Teams), an efficient base object for accumulating creative project experience and transferring this experience between company units and work groups.

Therefore, mastering the MTRIZ basics seems to the author to be an efficient and even indispensable component of project activities, worthy of integration into the EcoSpace megasystem creation process.

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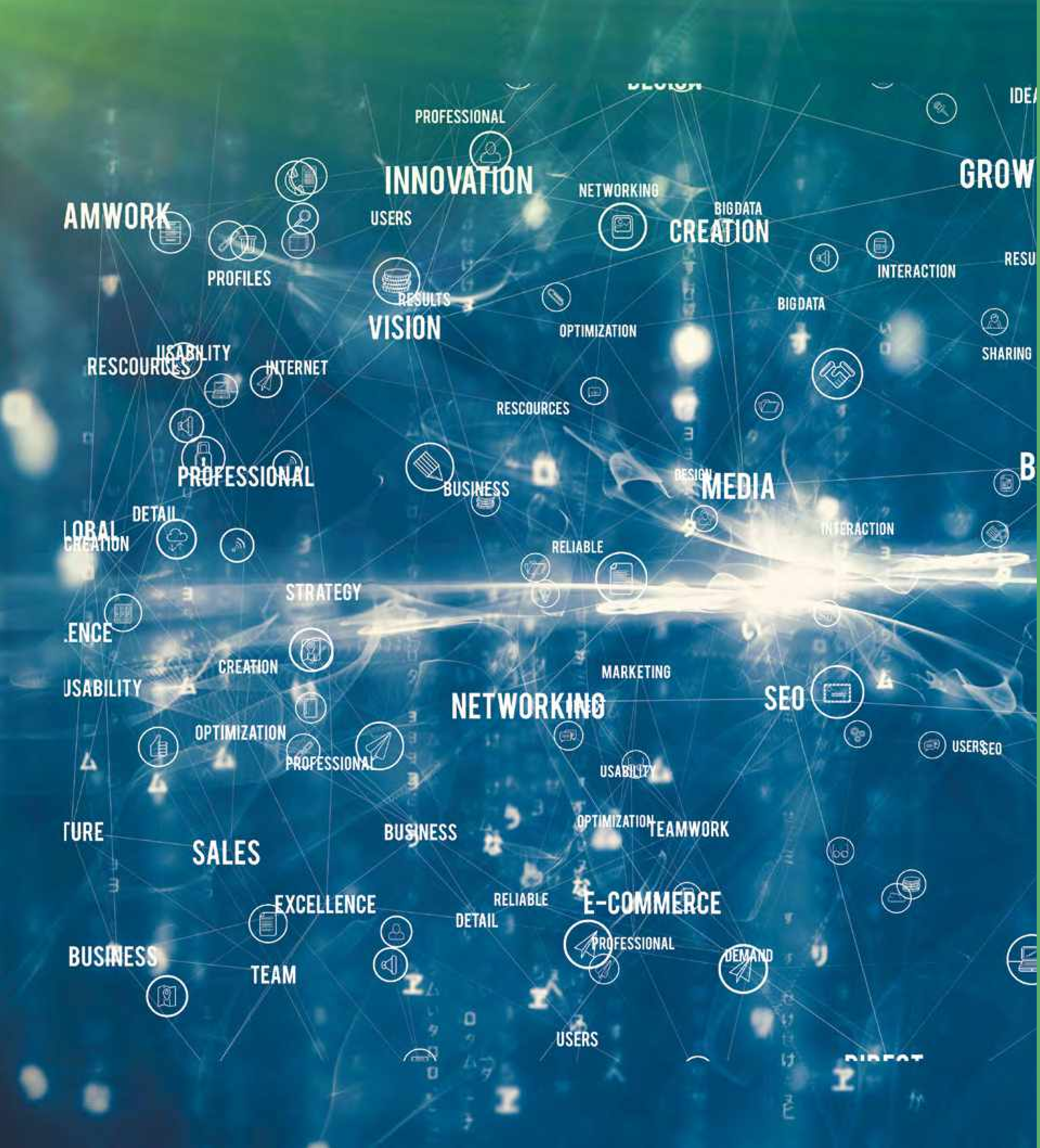

UDC 658.5

Special aspects of management methods for design of the EcoCosmoHouse facility on the planet Earth

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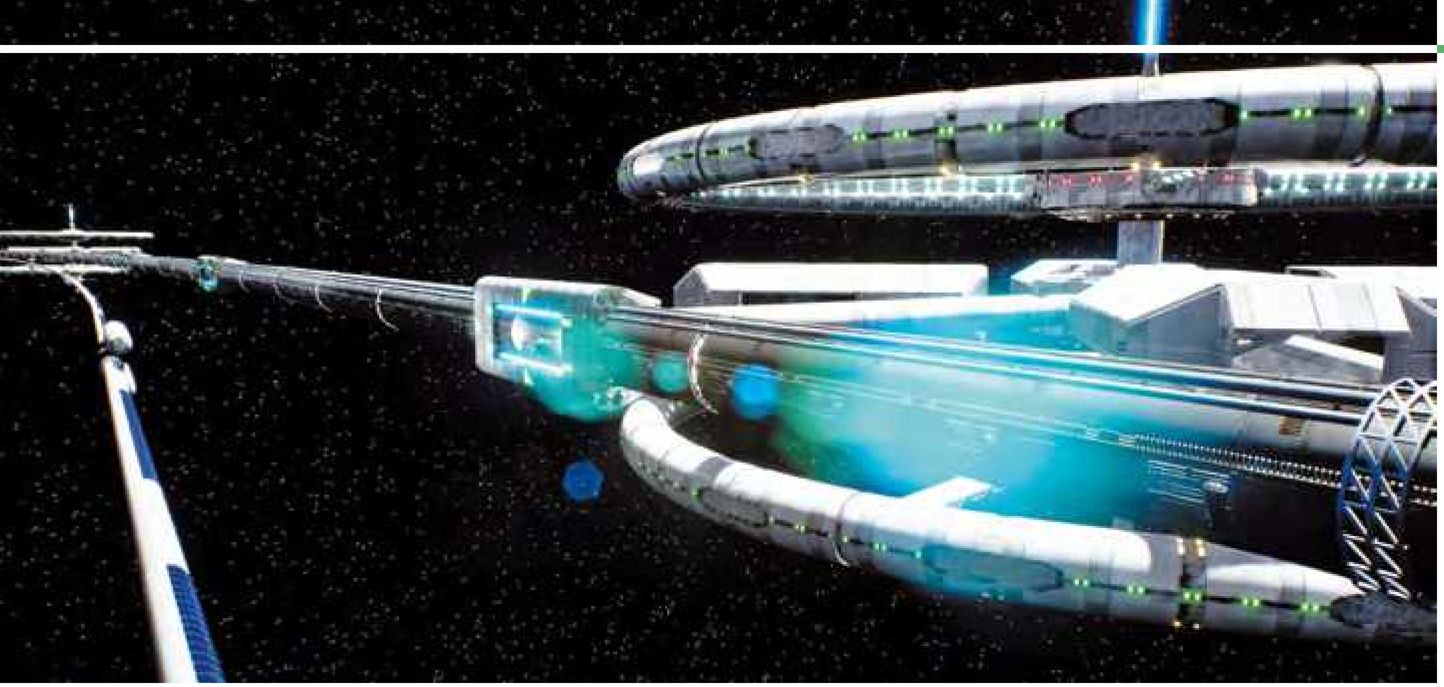
EcoCosmoHouse on the planet Earth (ECH-Earth) is a technically complex facility both in terms of design decisions and in terms of the managerial component of the project. In view of this, there is a need to form a new approach in the project management methodology, which can positively influence the design terms, interaction between specialists, be flexible to the multi-vector tasks set and contribute to their solution. The world experience of project management in various fields of activity is considered, the ENOVIA Program Management software is studied as a tool for project management.

Keywords:
EcoCosmoHouse on the planet Earth (ECH-Earth), project management, ENOVIA Program Management, 3DExperience.



EcoCosmoHouse on the planet Earth (ECH-Earth) as a construction facility is multifaceted, which entails many additional tasks [1]. In its implementation it is necessary to take into account a wide number of requirements in various areas, such as the creation of a closed ecosystem, ensuring the requirements of ecology, security, economy and construction. Another significant feature of this facility is the staging of its operation: the first stage is a profitable hotel business with a closed recreational area; the second is scientific studies of a closed biosphere as an analogue of a cosmic settlement. ECH-Earth is only a small part of the global program of space industrialization, covering the General Planetary Vehicle (GPV), the Equatorial Linear City (ELC), and the Industrial Space Necklace "Orbit" (ISN "Orbit"), which in turn includes biospheric EcoCosmoHouses, the model of which will be implemented in ECH-Earth [1]. One of the main tasks of the project on Earth is the creation of a self-contained, independent biosphere, which in itself seems to be a non-trivial task for design. Similar successfully implemented analogues in the world do not exist.

According to regulatory documents, ECH-Earth belongs to the first class of complexity (K-1: 5.1.2 Large-span buildings and structures with spans over 100 m and clause 5.1.20 Buildings and structures, the design and construction of which requires the development of Project Specific Technical Specification – PSTS) [2]. PSTS is a document containing technical standards developed for a specific capital construction facility. If during the design of different types facilities there is no possibility to comply with all the standards and requirements established by the legislation, or if the regulatory documents do not establish requirements for the facility, PSTS are developed that take into account these particular construction features.

In connection with the above, it is extremely important to choose the optimal method of project management before starting the design. Any project consists of a set of processes (initial conditions, requirements, achievements of the expected results of milestones, phases, stages, sequence of processes, tasks, operations), which have start and end dates for their implementation and should be a single system. The reference points of the project are called its milestones, which track the achievement of intermediate results. Upon receipt of results that meet specific prestated requirements, the project objectives are achieved. In the course of the project implementation, it is necessary to continuously monitor the tasks assigned for their implementation and compliance with the requirements of the customer. At certain milestones, the depth and degree of completeness of the tasks are assessed, the compliance of the results obtained with the established requirements, and if necessary, the subsequent plan is adjusted.

Project management methods have positive and negative sides. The choice of method and its application depend on the client's expectations, the type and content of the project [3]. The importance of competent defining a design management method can be realized by studying world experience and observing the successes and failures of largescale programs. For example, 400,000 NASA employees and 20,000 companies and universities participated in the implementation of the Apollo mission. The ambitious goal – landing a man on Earth's satellite and returning it back – required an incredible amount of resources, cooperation, innovation and planning. The task of managing this project was assigned to Dr. J. Muller. His key decision was to divide the project into several parts, which made it easier and more efficient to control all its component parts. The system developed by him showed its efficiency and the project was completed ahead of schedule [4].

For completeness of the analysis, the author of this article considers the world experience of project management in various fields of activity. The following methods and modes of management are analyzed: Adaptive Project Framework, Benefit Realization – BF, Agile, Critical chain project management, Critical path method, Kanban, Lean, PRISM, Process-Based Project Management – PBPM, Scrum, Waterfall, etc.

After the research, the main methodologies were selected, the key parameters of which are most suitable for the successful implementation of the ECH-Earth facility.

Agile. Flexible methodology, the key parameters of which are resources, team building, teamwork, cooperation and the search for compromises between employees. An additional important advantage of this methodology: participants in the process quickly make adjustments and produce a result. Agile encourages participants in the process to be focused on a specific task and eliminate temporary losses from work that are not related to the problem being solved, maximizing the efficiency of collaboration. Documentation in this approach has the second priority, and the main priority is to find a working solution and check the compliance of the found solution with the requirements [5].

Critical chain project management. Based on the formation of key tasks with the final date of completion of the project. Logical links built between tasks take into account possible limitations of temporary reserve funds. In other words, this method determines a certain critical path (sequence of tasks) with certain deadlines that, if violated, are compensated for by the time buffer allocated for unforeseen circumstances and planned in advance (a risk management mechanism is introduced). The main task of the critical chain project management is to create conditions for intensive work, to increase the team's efficiency by eliminating safety reserves of time in individual tasks. The method enhances the pay-off of the team, feedback and orients everyone towards a single result [6].

Kanban. Its distinguishing feature is the visualization of a constant flow of tasks, which helps to identify problem points, which allows to quickly respond and pay attention to tasks that are not performed [7].

PRISM. Methodology focused on the so-called "green" facilities and aimed at reducing the negative social and environmental consequences in project activities. PRISM allows for rational use of tangible and intangible resources, intelligent allocation of natural resources and takes into account factors that have an impact on the environment (direct and indirect) [8].

SCRUM. A method based on teamwork and problem solving at fixed time intervals, called sprints. The purpose of the sprint is to solve the problem. Development of the project in this method takes place with the help of iterations. The following rules are typical for SCRUM: planning and managing a list of requirements; iteration planning; interaction between members of the project team; analysis and adjustment of the development process. In this methodology, the role of a leader is very important, and the roles of each team member are clearly defined, with each of the participants having several roles. Most often, the SCRUM team includes about seven people, they themselves determine how to solve this or that problem. The methodology allows settling clear tasks that have a definite final goal. SCRUM is more focused on the product development process, rather than on the management process, and can complement another management process [9].

Waterfall. A cascading planning model in which tasks follow each other alternately, the end of one task or several ones usually means a milestone achieved. In this methodology, activity progress charts (Gant charts) [10] are used to monitor execution.

An important factor for successful project management is the use of suitable software products that allow, in conjunction with the methodology, to control the design process. ENOVIA Program Management – a product of the 3DExperience platform from Dassault Systemes – was chosen for research as an example of software containing the necessary functionality [11]. The main tasks solved with the help of ENOVIA Program Management are project initiation, its planning, execution, monitoring and control of assigned tasks, project closure. This platform is associated with the main software products used in the work (MS Office, MS Project, etc.). All this allows to quickly navigate the structure of the facility and quickly respond to various changes (setting tasks for performers, tracking resources, tracking and adjusting the schedule, storage and availability for the execution of the necessary information). The next advantage of the platform is as follows: with agreements and technical capabilities from any device anywhere in the world, you can connect to the project or connect a new participant.

The study showed that under the condition of the multivector uncertainty of the various parameters of the ECH-Earth facility and its multitasking, the use of a single, long-known methodology may be ineffective. Multitasking dictates its design management rules. Due to the fact that the tasks in the project are multidisciplinary, have a different focus, deadline, complexity, resource need and other criteria, for the effective management of this project it is necessary to focus on the key indicators of some of the methodologies considered: Agile and SCRUM – resources and their interaction, Kanban – a visual component of tracking results, PRISM – environmental aspects in the design, Waterfall – for certain tasks and tracking the entire design structure. It is also

important to modify the system, introducing or adjusting the methods and approaches used. The software used to manage the design should be focused on a specific facility, be flexible in terms of management, and also have a convenient user interface (usability). The software product should help to track critical places for timely response. A competent choice of methodologies, according to their key values, in combination with the software, qualified specialists and a clear understanding of the main goal contribute to the solution of all tasks and emerging problems that may occur in the design of the ECH-Earth facility, as well as more global facilities necessary for large-scale space exploration.

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UDC 316.6

Principles of building a healthy environment for human life, work, development and recreation in EcoCosmoHouse

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In the article, the portrait of a potential test resident of EcoCosmoHouse (ECH) has been analyzed, a range of human needs, that should be taken into account when creating a closed space for living, has been considered, and a number of principles for building a healthy environment with regard to biological, planning and organizational features that have an impact on physical and psychological health have been outlined. The work also highlights the need to consider the prospects of human development in order to create a space that matches future trends.

Keywords:
EcoCosmoHouse (ECH), sustainable healthy environment, hierarchy of needs, permaculture, salutogenesis, self-actualization.

Being born, a man initially has everything he needs for his life. On our planet the conditions for satisfaction of basic physical needs have been created evolutionarily, which made it possible for an earthling to be born: air composition, acceptable temperature range, availability of water, soil, food, diversity of living organisms, etc. A person is born in a family and immediately becomes a member of the "social unit", which implies that his social needs have everything necessary to satisfy them, as it is vitally important for a child. The needs for security, belonging and love are being addressed. In modern society, the first twenty years of each individual's life are so clearly arranged that the satisfaction of such needs as development, respect, and self-realization depend not so much on the efforts made, but on the perception of the surrounding world and events. For self-actualization and disclosure of internal potential, the whole world is open to a man, in which he is free to choose the forms of realization of these needs [1].

This article considers a number of issues. What happens if we try to create an isolated space for a person's life? What should it include, what should it consist of, in order not to stop, but on the contrary, to accelerate people's development in it? This is exactly the space that EcoCosmoHouse (ECH) becomes [2].

In order to create a healthy environment for life, work and recreation, it is necessary to define a list of needs that have to be taken into account in the newly formed space and society, by analyzing a psychological portrait of a potential test resident of the ECH, with regard to his "layer" of needs and opportunities for their development and growth. At the same time it is important:

- identify the lowest acceptable threshold of a personal development necessary for participation in the project as a test resident;
- consider the emerging community of test residents as a harmonious entity in which people complement each other in various aspects (professional, physical, emotional, etc.);
- keep in mind the need for self-development and personal growth as one of the basic needs of any human being;
- take into account the conditions of a closed space for human life, isolation from the usual natural elements, such as sky, horizon distance, the possibility to change the environment, etc.;
- take into account the conditions of a limited circle of socialization and the impossibility of changing it for a certain period of time;
- take into account the possibility of emergency and unforeseen circumstances;
- consider other factors influencing changes in behavior, health and personal perception within a closed space.

In order to obtain additional information on the possible criteria for selecting the residents of the ECH, we have studied the current requirements for astronauts during the selection to the FSBI "Research and Testing Center for Cosmonauts Training named after Yuri Gagarin" [3].

The main factors of selection are age, medical indications, anthropometric data (strict selection by height, weight and other parameters), physical training (endurance, strength, agility), higher education in engineering or flight specialties with work experience of minimum three years, ability to study and operate, knowledge of foreign languages and the basics of cosmonautics, absence of criminal convictions and criminal prosecution. Besides, special psychological studies and observations are carried out by expert psychologists. At the same time, individual (emotional, cognitive, volitional), social (degree of professional self-determination, interpersonal skills, aspirations and personality inclinations) and psychological characteristics are also analyzed.

For a better understanding of these issues, the social and psychological problems that have occurred in other experiments in closed ecosystems, such as BIOS-3 [4] and Biosphere-2 [5], have been analyzed. The general state of people in those projects was influenced by both external factors (lack of oxygen, food, hard daily work), leading to the deterioration of health and, as a consequence, to the suppressed moral state, and interpersonal relations. The difficulties experienced by the research participants divided them into groups with opposing views and caused conflicts. These disagreements, in turn, triggered a further deterioration in the already precarious health state.

Before EcoCosmoHouses are built in orbit in the future, the principles of constructing closed ecosystems with a particular society inside have to be tested on the Earth.

From the above-mentioned it can be determined that criteria for selecting test residents for the EcoCosmoHouse on the Earth (ECH-Earth) have to include physical characteristics of the person (health, physical training), presence of necessary knowledge (general, professional and about research subjects) and certain psychological qualities (personal and social). Additionally, the author of this article suggests further consideration of a candidate selection system on the basis of the "team matrix" – a system where the necessary characteristics of a single team are distributed to its individual members, creating avatars of future specialists that form a team fully functional to achieve specific purposes.

To form an idea of a number of conditions that need to be organized in the ECH, different theories of human needs have been studied. Examples may include the pyramid of A. Maslow [1] and the spiral dynamics of K. Graves, D. Beck and K. Kovan [6]. Both systems are hierarchies of needs, reflecting the development of human consciousness, as well as society as a whole, from the physical level, which includes only a range of personal needs, to the level of full potential with a global vision and an integrated approach [7]. Moreover, being at higher levels of development does not deny the need to meet the needs of previous levels, but, on the contrary, emphasizes their implementation as a basis for further growth. Thus, it has been stated that it is necessary to ensure the satisfaction of the full range of needs to make a person's life worth living in an enclosed space: from basic physiological needs to full self-actualization.

Since modelling the conditions for meeting basic needs is the basis of the entire experiment, they have to be given due priority. And it is important to note that this basis implies a harmonious combination of all physical components of the biosphere not only for humans, but also for animals, plants and other living organisms. These components include: maintenance of climatic parameters, compositions of air, soil, water, availability of necessary quantity of a foodstuff containing the necessary vitamins, micro and macro elements, a variety of plants, animals and other elements of the nature.

If we turn to the planet Earth as the only analogue of favorable conditions for life of Homo sapiens, it becomes obvious that the basis of these conditions is Nature. Consequently, in a closed artificial biosphere it is necessary to form the most natural conditions for human habitation in combination with the necessary technical achievements of civilization.

The modern natural way of organizing space, landscaping and farming is permaculture [8]. The advantage of this approach is the use of natural rather than nature-like technologies. Creators and followers of this direction are nature observers who equally value the care of the Earth with all its components of living and non-living nature and care of people. The main principles of permaculture are harmonious interaction of all elements of the environment, where each of them has several functions and provides existence to other elements, application of various types, copying of natural schemes and algorithms, effective energy planning and use of renewable and biological resources. Designing natural ECH areas in accordance with the principles of permaculture will allow creating the most natural relief and landscape features, natural interconnections of ecosystems, their effective interaction and human life as part of the bio-world.

However, providing all the necessary physical conditions for a person's life is not enough for people to be healthy. Besides physical parameters there are also psychological ones which in a context of survival can be reduced to the concept of stress tolerance. If we take into account the results of psychological researches, we will see that 20 % of people in crisis situations need the help of professionals [9]. People of this segment are the subject of interest to Western medicine specialists, whose work is aimed at identification and treatment of diseases that have already occurred. In health psychology, this focus on disease management is called the "Pathogenic Paradigm". However, in the opinion of the author of this article, while creating a new space for people's lives, it is necessary to consider first of all the options for providing such conditions that would not only treat diseases, but also initially did not allow the possibility of their onset. This approach, named by A. Antonovsky, professor of medical sociology, is known as salutogenic (salutogenesis comes from the Latin salutis which means health and the Greek genesis which means origin), which is literally oriented to the study health origin [10].

The subject of Antonovsky's research was the psychological characteristics of people who experienced stress to various degrees, such as those who survived concentration camps, and not only retained their health, but also remained happy. The conclusion of these studies is that the impact of stress on people is determined by their individual ways of responding to the situation. The most resistant to stress are people who perceive the world meaningful and manageable. "Sense of coherence" is the feeling of connection, coherence, typical of such people, which allows them to assess objectively emerging threats and perceive them as challenges that bring new opportunities, as well as to assess their own resources required to solve the problems [11]. That is exactly the attitude that ensures good health.

How can one use the principles of salutogenesis in designing the environment for human life? The need to create understandable, easy to perceive, comfortable, safe and manageable conditions, in other words, a sustainable and healthy environment, becomes obvious. It is also important to focus not only on risk factors and disease treatment, but also on factors that preserve and improve health. Such an approach is possible only with the systematic introduction of the question "What else can be improved or envisaged to maintain and improve health?".

Since there are many lifestyle related diseases in the world today (obesity, diabetes, respiratory diseases, cardiovascular diseases, etc.), it is important to focus on such planning and architectural solutions that encourage a healthy lifestyle: picturesque walking areas, convenient sports grounds, aesthetic inclusion of architecture into natural environment, ergonomics, suitable illumination, absence of destructive oppressive elements (noise, "poisonous" colors, tangible vibrations, unpleasant smells). Availability of healthy and tasty foodstuffs and their proper preparation, absence of knowingly harmful products (containing large amounts of sugar, preservatives, stabilizers and other harmful chemicals) are no less important for human health. When organizing a space, it is important to approach competently the creation of zones for people's social activity (communication, work, education, interaction, creativity) and for a private rest, necessary for psychological well-being [12].

Equal value of physical and psychological comfort is emphasized by various studies in the field of influence of the person's psychological state on his health and the health of others, and consequently, on any other sphere of life. For example, K. Porat from Georgetown University studied the impact of rudeness in a workplace on the financial results of the company [13]. Many people admit that rude words, voice increase, impudence and disrespectful remarks, especially from managers, have a negative impact on the emotional background of any team, but few people realize that such behavior leads to quite material costs. The survey revealed that 47 % of employees consciously work less or less intensively, with less creativity, 80 % feel offended instead of working, 78 % admit that they are disappointed in the company, and 25 % admit that they take out their irritation on clients and other employees. Cisco, an American multinational networking company with a reputation for being an exemplary employer with a friendly and polite team, became interested in the survey findings. The company estimated only three types of costs and made a detailed estimate, according to which it turned out that due to the violation of courtesy standards it loses 12 million USD per year.

Any rudeness is a spark that ignites the fuse of the psychological state in a certain group of people and even more, as communication continues in families and other groups. And if we are talking about a closed space with a limited circle of communication, as in the case with the ECH, the creation of a friendly atmosphere and the selection of participants with the appropriate character features are among the factors that determine the success of the experiment, and in the future the entire mission of space exploration.

Thus, having analyzed physical and psychological needs of a person, the first reference points and principles of a healthy environment formation in a closed artificial biosphere have been received. However, if these needs are to be met in the long term, their subsequent development must be taken into account. That's the way a person behaves: he always needs to move forward. You can't stay where you are, there are only two ways: either development or degradation. And no EcoCosmoHouse should

become the place that will hide the potential of Homo sapiens. The need for further development and self-actualization of each individual is comparable to the need to unlock the potential of all mankind in their aspiration to develop and go further, into space, beyond existing borders. This is just as obvious as the next stage in the technocratic path of the entire civilization development – space industrialization and removal of all industry harmful to the biosphere beyond its boundaries [2]. The only person who can do that is a happy, healthy person.

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UDC 574.44

Trophic chains and biological rhythms as the basis for the creation of the EcoCosmoHouse biosphere

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The article discusses the conceptual aspects of creating EcoCosmoHouse (ECH) from the point of view of studying trophic relationships and biological rhythms. An author's scheme for constructing a multilevel model based on trophic networks with a certain set of interrelations (permanent, temporary, random, and hypothetically possible) is given. The model allows systematizing all biological organisms and serves as a basis for understanding the energy balance in the environment, with the analysis of individual points in biorhythmology and indicating the optimal abiotic conditions, the number of individuals, etc. The proposed model allows not only to regulate, but also to identify ways to solve the problems of the possible death of certain types of organisms, to regulate disturbances of biospheric homeostasis.

Keywords:
trophic cycles, trophic networks, biorhythmology of living organisms, biodiversity, transformation and development of the ecosystem, multilevel dynamic network model for controlling the homeostasis of the artificial biosphere, artificial ecosystems, EcoCosmoHouse (ECH).

The EcoCosmoHouse (ECH) biosphere is defined as a closed volume that includes many communities of living organisms capable of self-reproduction and full-value existence under the influence of a complex of abiotic factors for an unlimited time. On the one hand, this is an artificial ecosystem, as it will be created by an engineer, on the other – natural, since all living organisms will be delivered from the planet Earth without any changes (including genetic modification) – from the terrestrial biosphere, which has billions of years of evolution. Since the entire biosphere cannot be recreated in the ECH, but only its simplified, local model, it will be artificial only in this sense. At the same time, a closed local ecosystem is a rather narrow concept that includes separate biosystems consisting of communities of living organisms from different habitats and their systems of established trophic relationships that exchange matter, energy and information between them.

Designing closed artificial ecosystems is one of the most urgent problems of humankind. First of all, it is dictated by the space age [1, 2, 3], secondly, by the need to understand a whole range of biological processes that would allow not only to model full-fledged biospheres, but also to enable the restoration and developmentof ecosystems [4].

In connection with the above, the purpose of this work is to build a model of homeostasis regulation of the local biosphere of EcoCosmoHouse based on trophic relationships and biological rhythms.

The most well-known large-scale projects in this field are BIOS-3 [5, 6] and Biosphere-2 [7, 8] projects. As a result of their implementation, colossal experience has been obtained, the analysis of which indicates a number of issues and problems in regulating the existence of biological organisms in a closed local biosphere. At the same time, this experience became the basis for modeling small artificial ecosystems (for example, EcoSphere Closed Ecosystems, AquaMir, Eternal Terrarium closed ecosystems, etc.), showing their viability for about 2–15 years (scientific experiments on this subject are almost absent).

A good example of an accidental creation of an artificial ecosystem is the experiment of an electrical engineer from Cranly (Surrey, UK) – D. Latimer, who in 1960, out of curiosity, planted four seedlings of Tradescantia into a huge glass bottle and closed it. Only one plant survived, but it formed a mini-ecosystem that has existed for about 60 years [9]. Considering this model, we can conclude that the water, evaporating from the surface of the soil and plants, condensed on the walls of a glass vessel, thereby carrying out the watering of the plant. Oxygen, which was produced in a closed system, was absorbed in the process of rotting of fallen leaves. The carbon dioxide formed was reintroduced into the process of photosynthesis. Thus, such small ecosystems can serve as an example of a practical approach to developing mechanisms for maintaining the viability of artificial ecosystems.

The basis for modeling artificial ecosystems is the establishment of homeostasis at all levels of organization of communities of living organisms, taking into account the regulation of abiotic and biotic factors. At the same time, it is important to use the concepts of trophic chains and biological rhythms. It is the organization of the trophic structure of communities of living organisms with regard to seasonal rhythmics that the stability of the corresponding cenoses depends on.

The trophic (food) chain is the transfer of substances and the energy contained in them from autotrophs to heterotrophs, which occurs as a result of the consumption of some organisms by others [10]. That is why the trophic structure within the EcoCosmoHouse [4], which we consider as a cycle (Figure 1), is of particular importance. This approach allows clearly understanding the role of each of the biological components of an artificial ecosystem.

However, trophic cycles can be the basis for building an appropriate energy balance. When moving to each level, moving from producers to decomposers, there remains about 10 % of the energy from the more energy-intensive level (R. Lindeman rule) [11]. For the graphic display of thetrophic structure of a biocenosis, the pyramid model [12] is used (Figure 2), which can reflect the number of individuals (a pyramid of numbers), their biomass (biomass pyramid) or energy contained in them (energy pyramid).

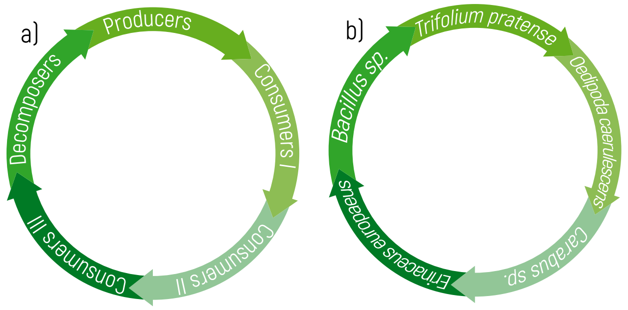

Figure 1 – Trophic cycle with indication of the corresponding trophic level:
a – trophic cycle with indication of trophic levels;
b – a specific example of a trophic cycle

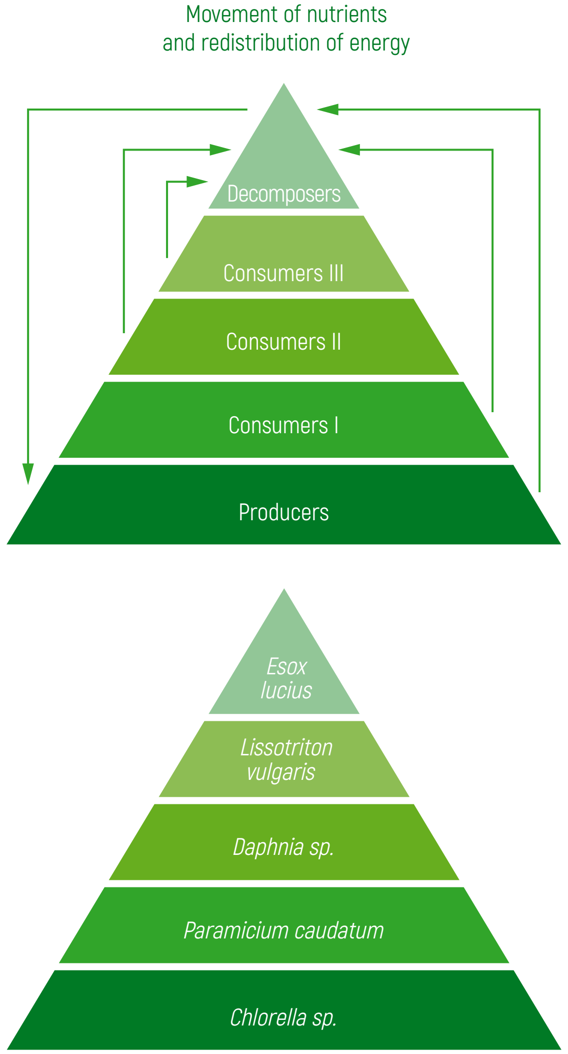

Figure 2 – Biomass Pyramid

To fully understand the structure of the interaction of trophic chains, it is proposed to use trophic networks (Figure 3), which would include the nutritional relationships of a number of organisms. In food networks, the following types of communication are distinguished: permanent, temporary, random, and hypothetically possible. Permanent relationship is a relationship that occurs with high frequency or permanently (for example, the relationship of monophages). Temporary relationship is a relationship formed under certain conditions (for example, during outbreaks of mass reproduction). Random relationship is a very rare relationship, having a random nature. A hypothetically possible relationship is the alleged emergence of a relationship based on the trophic level, behaviour and trophic preferences.

The gradual expansion of the network model (due to the large number of biological organisms included in the ECH) has led to the fact that there is a need for unification and reduction to a single model reflecting the general structure of communities of living organisms. In this regard, the authors propose the use of a multi-level dynamic network model for regulating the homeostasis of the artificial biosphere, which with a gradual filling would take a spherical shape (Figure 4).

For the operation of this model, the authors introduced the following rules: each species of living organisms is entered into the model only once; each species of biological organisms can have an infinite number of food links, but not less than one; relationships in the model can be both vertical and horizontal; when creating a network, it is necessary to take into account the nature of the interrelationships of biological elements of the ecosystem (permanent, temporary, random, and hypothetically possible): the wider the network and the more accurately the nature of the interconnections in the multilevel dynamic network model for controlling the artificial biosphere homeostasis is indicated, the more qualitative tool can be obtained; possible dynamic transition of any organism to any of the trophic levels due to the change in the trophic level for a specific food chain, etc.

The proposed model, based on trophic levels and relationships, is a database of a number of biotic and abiotic indicators. The following scheme can serve as a protocol for filling: the name of a living organism, the trophic level(s), the trophic relationship(s), phenology, information about the features of biorhythmology, the amount of food consumed, gas exchange, methods for identification and possible ways of regulating the number, etc.

Such a model will become not only a basis for understanding the entire system of relationships between living organisms, but also serves as a tool for understanding the flow of all energy processes taking into account abiotic

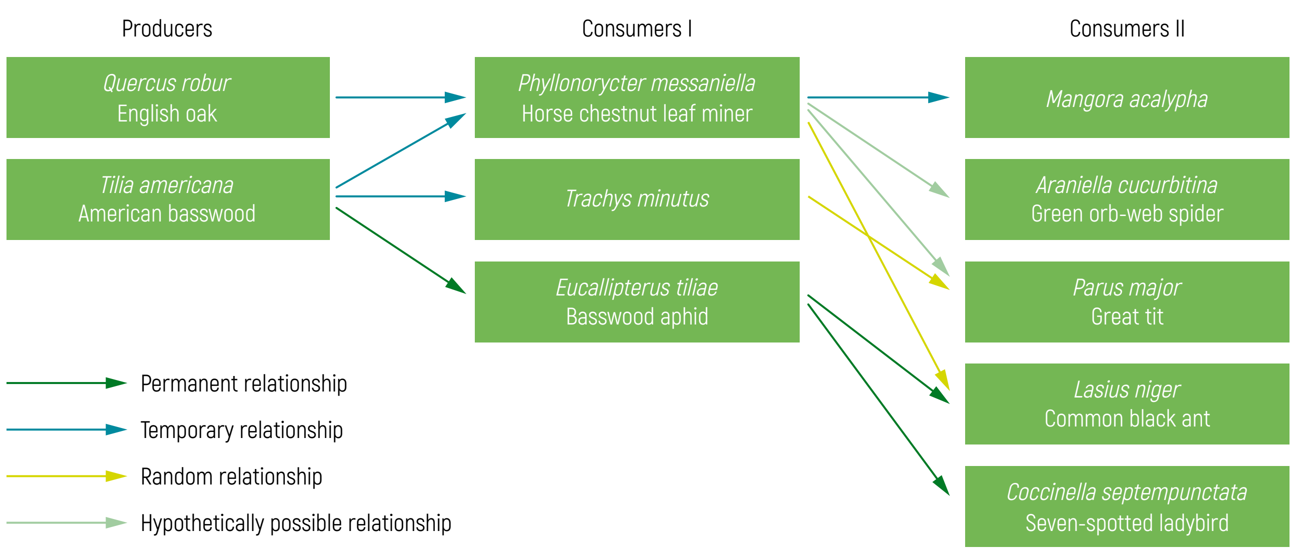

Figure 3 – Fragment of the ECH trophic network

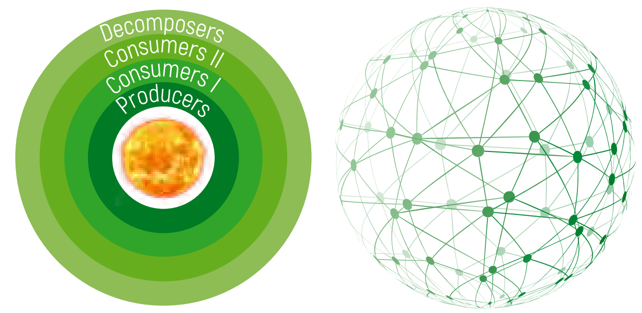

Figure 4 – Multilevel dynamic network model
of homeostasis regulation of artificial biosphere

factors, which will allow calculating a specific number of organisms in the ECH (which was previously calculated very tentatively). The death of certain types of organisms, reduction or outbreak of any of the elements of the trophic network can lead to catastrophic consequences, however, having such a full-fledged model, one can not only regulate, but also determine all possible ways to solve the problem, which means that the violation of the biospheric homeostasis can be solved as soon as possible, etc. In addition, within the framework of this model, it is planned to provide for a biorhythmology of living organisms. Biological rhythms are periodically recurring changes in the intensity and nature of biological processes [13]. In some cases, biorhythmology leads to a change in the nature of nutrition of living organisms. In this regard, this moment can also be considered as part of the proposed model, forming a highly sensitive tool for creating a highly efficient closed ecosystem. It is recommended that the described model be implemented in the form of appropriate software (some of the elements of the corresponding model are indicated above).

The main problem of this approach is that, with all its advanced studies of living organisms, the scientific world still has very little understanding of the trophic relationships and biological rhythms of individual organisms. The accumulation of equilibrium information in ecosystems is still happening. In addition, new species of living organisms, which also occupy a certain place in the established systems, are described annually. The work is complicated by the fact that an artificially created set of conditions leads to the fact that a number of minor and/or additional relationships between organisms can take on a basic character. Moreover, new connections may arise, which may lead to destabilization of the developed scheme of interaction between living organisms. All this should be maximally investigated and structured on the basis of the proposed model. Subsequently, it is this approach that will allow not only for the transformation of the ecosystem, but also for control of its development and improvement.

Considering the biological structure of ECH, it is necessary to take into account the fact that living fertile soil is the basis of life and the immune system of any biosphere, including the local one. We take it unchanged – the living soil from the planet Earth with thousands of species of microorganisms, about a trillion individuals per 1 kg of soil. To create the ECH, we assume the use of more than 2,500 species of plant organisms (more than 2 million individuals), over 4,000 species of animal organisms (about 2.5 million individuals), which will form the basis of the existence of a local ecosystem. At the same time, the microflora and microfauna will occupy a central place among them in soil and aquatic environments.

For the full existence in the ECH, it is necessary to provide about 1,000 m^2 of soil surface per person, of which (approximately): 10 % – for the production of oxygen (taking into account the use of chlorella), 50 % – for plant foods (vegetables, fruits, herbs, grains, etc.), 40 % – for animal foods (meat, milk, cheese, etc.) However, with modern developments and optimization of processes (natural and technological for the production of oxygen, increasing soil fertility, etc.) under ECH conditions, the required soil area per person can be significantly reduced – twice or more. For the production of food that is sufficient for the full nutrition of one person, the following number of farm animals should be maintained in the ECH (approximately): 1/50 of a cow, 1/20 of a goat, 1/10 of a pig, 1/10 of a lamb, 1/30 of a bee colony, five quails, two hens. In addition, the optimal need for fruits, herbs and fish will be provided with such specific indicators (in terms of one person) of trees, shrubs, garden beds, water surface (approximately): 1/2 of an apple tree, 1/2 of a pear tree, 1/2 of a peach tree, 1/2 of an apricot tree, 1.2 of a plum tree, 2 m^2 of parsley and dill, 10 m^2 of microgreens, 10 m^2 of fresh water, etc. (Figure 5).

Thus, an integral part of the process for creating a closed local biosphere should be the consideration of trophic relationships and biological rhythms. Having reviewed some quantitative data on the number of living organisms in EcoCosmoHouse, we can conclude that the proposed multi-level dynamic network model for controlling homeostasis of the artificial biosphere solves the problem of structuring and managing closed ecosystems.

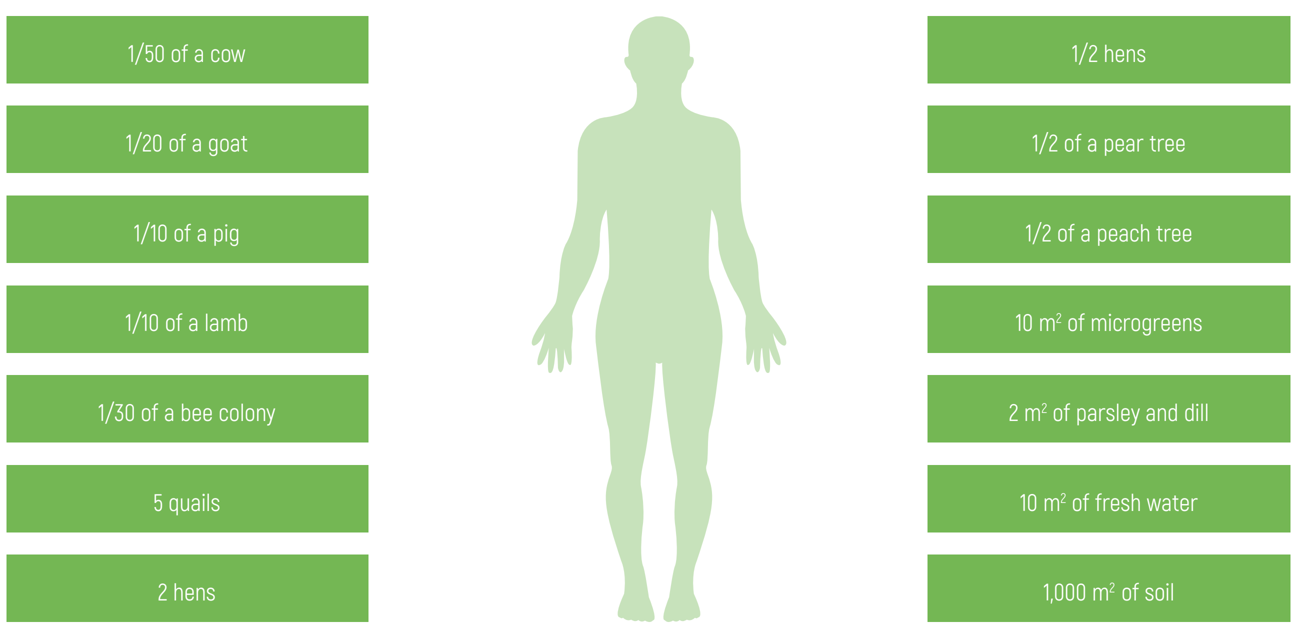

Figure 5 – Diagram of some elements of food for the full existence of one person in the ECH.

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UDC 581.9

EcoCosmoHouse as a space for the conservation of species diversity of tropical and subtropical flora

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The article discusses the problems of preserving the biodiversity of the planet Earth and the possibility of constructing EcoCosmoHouse (ECH) as a closed artificial biosphere to preserve the species diversity of tropical and subtropical flora. Particular attention is paid to the creation of fertile natural (living) soil and optimal soil profile for the best growth and development of various plant species.

Keywords:
biodiversity conservation, tropical plants, vermicompost, structured soil, reintroduction.

It is known that the problems of conservation and rational use of natural resources (including the plant world) are currently highly topical. Biological diversity is the basis for maintaining environmental conditions of the environment, economic development of the society. There is an obvious need for the development and implementation of effective measures for the preservation of the world's plant biodiversity. In their study, N. Pitman and P. Jorgensen calculated that out of 300,000 to 420,000 plant species 94,000 to 193,000 are endangered worldwide [1].

Without studying tropical plants, it is almost impossible to understand the paths and laws of the evolution of the Earth's plant world. Crop production in tropical latitudes provides many useful and irreplaceable products: bananas, pineapples, vanilla, black pepper, rubber, coffee and cocoa. A large number of medicinal, aromatic raw materials are transported from tropical countries. One of the objectives of the Global Strategy for Plant Conservation is to save plants that are socio-economically valuable for humanity: fruit, textile, aromatic, medicinal [2]. The concept of EcoCosmoHouse (ECH) involves the modeling of environmental conditions as close as possible to the tropical and subtropical zones [3]. This will allow receiving products all year round and growing different types of plants in this zone, as well as providing comfortable conditions for ECH residents.

Creating a variety of flora within the ECH, we prepare not only the optimal conditions for the development of a closed ecosystem, but also the basis for solving a number of environmental problems, form a collection of living plants. Subsequently, it can be used for the reintroduction of rare and endangered species into anthropogenically modified biotopes, the development of a current range of species for modern urban landscaping.

The highly significant function of ECH plants is the production of oxygen and the removal of carbon dioxide. Green areas can provide maximum autonomy for ECH residents in food, medicines and other resources. Another significant function is the creation of comfortable conditions for a man. Plant compositions should be harmonious and aesthetically pleasing, therefore, the exposure of ECH plants can be supplemented with decorative-leafy and flowering plants such as pitai, strawberry pear *Hylocereus undatus*, *Canna L.*, chionodox *Chionodoxa Boiss*, nomadic *Athyrium Roth*, etc.

The flora of Belarus includes about 4,100 species of higher plants [4]. In recent years, the problem of biological diversity and its conservation has been given great importance. It is known that one of the ways to preserve and restore rare plant species is their introduction into botanical gardens. Almost the only organization in Belarus conducting a serious bioecological study of the culture of rare and protected plant species is the Central Botanical Garden of the National Academy of Sciences of Belarus.

The second in a row (but not least in value) facility involved in the conservation of plant biodiversity can be the EcoCosmoHouse on planet Earth (ECH-Earth) of about 2 hectares. Conducting a series of research tests in ECH-Earth in Belarus will allow assessing the possibility of spreading the species diversity of plants on the planet Earth in colonies in near-earth orbit.

Considering all the above factors, when creating the ECH, natural technologies or those as close as possible to them should be used. Using modern equipment in harmony with nature, many natural processes, such as humus formation, can be improved and accelerated. Obtaining humus in the soil in the right quantity and quality is necessary to maintain the biodiversity of the flora, as it accumulates a large number of macro- and microelements, growth substances and vitamins that are directly absorbed by plants. The nature and speed of humus formation depends on a number of factors, the most important of which are the structure of the soil profile, water-air regime, the composition of the microflora and its activity. Thus, an important point is the creation of an optimal soil structure for planting tropical and subtropical plants, as well as for the natural course of the process of humus formation.

For a comfortable growth of woody plants in ECH-Earth, an average thickness of the soil profile of 1.3 m should be prepared. In the upper layer of 0.3 m, the use of humus from brown coal with the addition of biohumus is permissible. It is worth noting that over the entire area of ECH-Earth this value will be non-permanent. In places where the ground is poured on the foundation, in the zone of streams and lakes, the thickness and composition of the soil profile will differ.

When preparing the soil, it is possible to use local soil. It should be borne in mind that too heavy unstructured soil in the composition of the turf soil (more than 50 %) can lead to stagnation of water in the upper layers of the soil. Consequently, water will not penetrate into the root zone of adult trees, as a result of which it is necessary to deposit structured soil separately for each plant.

As one of the options for bulk soil, it is proposed to use structured soil from the following horizons: top fertile soil with a high concentration of microorganisms (humus, 30 cm thick), eluvial (sod land, 40 cm), illuvial (sandy loam with added crushed brown coal, 45 cm) and a drainage layer (crushed stone, 15 cm; sand, 15 cm). The fertile top layer consists of humus, biohumus, transitional and lowland peat, sod land.

Back in the 60s of the last century, it was shown that the introduction of brown coal in the soil leads to an increase in crop yields [5]. Brown coal is rich in humic substances and potentially it produces quite high-quality fertilizer, especially in combination with nutrients from various types of organic raw materials (in this case, biohumus can be used) [6].

When preparing the soil, it is proposed to use humus with the addition of biohumus from brown coal. As a result of the tests, it was revealed that the biohumus from brown coal contains the maximum number of microorganisms that assimilate the mineral forms of nitrogen, which exceeds the control (substrate without vermicomposting) indicators by 128 %. A high number of ammonifying microorganisms is observed in the variant with biohumus, obtained on the basis of straw manure of cattle, and is 5.96×10^9 CFU/g. As can be seen, the introduction of conventional biohumus into the soil is not excluded.

For counting microorganisms, a quantitative method for counting viable cells in substrate samples was used [7]. Consideration of the main ecological and trophic groups was carried out by seeding on agar media. Mass fraction of total nitrogen was determined according to GOST 26715-85 clause 1, phosphorus – GOST 26717-85, potassium – GOST 26718-85 [8]. The content of humic substances was established according to STB 2392-2014 clause 5.7 [9].

Historically, the use of liquid biohumus has evolved from horticultural practices such as soaking manure or some plants in water, and the resulting liquid was used as a fertilizer and for sheet treatment against diseases and pests.

Tests of samples of liquid biohumus showed a high content of humic substances (more than 60 %), as well as general forms of nitrogen, phosphorus and potassium (5.1 %, 3.8 %, 9.6 %, respectively). On this basis, liquid biohumus in diluted form is proposed to be used as a top dressing of plants and for their sheet processing.

The results of the test of vermicompost confirm the value of its use for the creation of soil grounds for landscaping the ECH territory; liquid biohumus – for processing and feeding plants. When modeling plant species diversity under ECH-Earth conditions, it is necessary to take into account the minimum set of factors, such as lightness, soil selection, temperature and humidity (air and soil).

Thus, when solving the problem of biodiversity conservation on Earth, EcoCosmoHouse can serve as an alternative to specially protected natural territories, which are undoubtedly influenced by external factors and climate change. In addition, the ECH (taking into account the creation of an optimal soil structure) may be the first facility to preserve the biodiversity of the flora outside our planet.

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UDC 658.14.01

Economic replication model of the EcoCosmoHouse facility on the planet Earth

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The article reveals the peculiarities of the economic model used to estimate the investment attractiveness of EcoCosmoHouse on the planet Earth (ECH-Earth), and also gives an analysis of factors influencing the increase in its capitalization.
The peculiarity of the proposed economic model is not only to identify the key factors and drivers affecting capitalization growth of the facility, but also find their optimal ratio.

Keywords:
capitalization, key growth drivers,
main growth factors,business cost management model,
EcoCosmoHouse on the planet Earth (ECH-Earth).

EcoCosmoHouse on the planet Earth (ECH-Earth) is a facility with a multifunctional purpose. It simultaneously demonstrates the possibility of creating a closed biosphere, solves problems in the field of scientific-applied aspect of maintaining and developing human life in limited conditions and space, helps to preserve biodiversity and create a bank of living organisms of the Earth's specific climatic zones [1].

Solution of the above mentioned tasks requires special attention to the economic aspect, because a scientifically justified project, supported by economic sense, will allow to spread the idea of ECH-Earth, making it investment attractive for the business community.

The concept under consideration in this article is studied from the point of view of capitalization management tools (factors and drivers) in the format of asset value management economic model.

ECH-Earth is a multifunctional project. It is considered as a hotel with a recreational area, which has a special shape of a building; as a farm providing food for its inhabitants due to biohumus production technology; as a closed biosphere, which implements a full circulation cycle of substances, energy and information necessary for people, animals and plants to live in it; as a scientific experiment, which demonstrates the possibility of creating a space for human habitation in any conditions, including the near-Earth orbit, – all these factors make it impossible to apply a standardized approach to estimating the investment attractiveness of a project.

Different approaches can be used to address the issue of estimating economic expediency: functional and cost analysis suggested by Y.M. Soboleva, L.D. Milesom, E.A. Gramp; investment project payback calculation (NPV estimation); estimation approaches to doing business (cost-based, profitable, comparative). However, all of them have their own purpose and do not provide the effect necessary for management, but only solve the problem of estimating the investment attractiveness of assets.

In order to estimate technical and economic indices and possibilities of managing ECH-Earth assets capitalization, the authors have applied a new economic model, which integrates methods into a single system, which allows not only estimating economic efficiency, but also managing the capitalization of assets.

The concept of "capitalization management" in this article stands for the influence of the management entity on the change in the company's asset value (capital) as a result of the impact on the cost factors, the outcome of which can be estimated by changing the level of capitalization, using the appropriate estimation methods [2].

The specific feature of the proposed model is the implementation of the following logic: ECH-Earth project is multifunctional. It means that the main groups of factors influencing capitalization can be singled out (index C stands for capitalization).

Adding the payback period (PBP) and Breakeven Point (BEP) indices to index C, as well as selecting 3–4 key drivers in each of the project functions, which lead to the growth of ECH-Earth capitalization, we will get a comparative alternative model, which allows not only making decisions based on economic estimation, but also demonstrating the growth of investment attractiveness through the growth of ECH-Earth asset capitalization in the real time mode using a cube-shaped 3D-model. With the help of the key drivers formed on the basis of the optimization model, it is possible to develop and implement a financial strategy of capitalization management, planning their implementation at each stage of the project development.

Just as the construction of any house begins with a foundation, the proposed economic model is based on a solid basis that ensures the sustainable development of the concept to achieve its purpose. At this stage, building a "solid basis" for the purpose of cost management will interact with a group of ECH-Earth factors linked to the hotel complex. Since the purpose of ECH-Earth is to demonstrate the capabilities of the facility itself, and this possibility is provided financially mainly due to the presence of a hotel complex, it will form an initial economic model to estimate the investment attractiveness, and in the future it will be used to manage capitalization.

The construction of the economic model is based on the morphological analysis and identification of key factors and their corresponding drivers, which can have the most significant impact on the capitalization and estimation of ECH-Earth investment attractiveness [3]. The following groups of factors have been identified, related to:

1) tourism and hospitality – hotel rooms with infrastructure and engineering networks;

2) rest and recreation area – ECH-Earth facilities to provide rest and maintain a healthy lifestyle;

3) biosphere and farming – use of soil within ECH-Earth, filling its space with flora and fauna, growing foodstuffs;

4) technology of creating a closed ecosystem – constructive solutions, closed-loop technologies that ensure the circulation of substances in a closed artificial biosphere, as well as the processing of various types of waste;

5) scientific work – training programs, scientific and applied researches;

6) adaptation of the facility – activities that provide accommodation in areas where the negative impact of the external environment is high.

The development of each ECH-Earth factor makes it possible to estimate the phased effect of its influence on the capitalization of assets (C), payback period (PBP) and breakeven point (BEP), as well as to carry out an express estimation of the management decisions ranked in importance (key drivers of value growth), which affect the growth of the ECH-Earth investment attractiveness. Additionally, at the design stage, in order to increase the attractiveness of the facility for investors, it is also possible to form design features of ECH-Earth.

Selection of these three criteria (BEP, PBP, C) allows managing the facility in operational, tactical and strategic ways, forming and estimating solutions at all stages of the project life cycle.

In this research, one of the factors (a hotel complex) and a group of drivers are used as an example to consider the impact on the capitalization index, payback period and breakeven point. Other groups of factors, which also influence the investment attractiveness of ECH-Earth, are taken into account in the model, but their characteristics are not reflected in this study.

In order to estimate the impact of a group of factors related to tourism and hospitality, appropriate drivers for increasing capitalization and accelerating the payback period of investments have been identified and grouped into four main subgroups:

1) physical drivers. Measurable values that can be estimated in natural measures: pieces, square meters related to space constraints;

2) cost drivers. May have cost estimation and are subject to financial restrictions;

3) personal drivers. Connected with the participation of people, affect the business final cost due to the implementation of operational processes;

4) temporary drivers. Influence capitalization, related to time resource constraints throughout the entire life cycle of the project.

This grouping of drivers is seen by the authors as universal, because it does not contradict the physical and economic laws and allows analyzing the impact of drivers for any type of facilities at any stage of its life cycle, using, for example, a morphological matrix [4]. Matrix formation is the process of how, using individual bricks and blocks, a common model is built to manage capitalization and estimate the impact on the investment attractiveness of the project. An example of building a similar matrix is shown in Table 1.

When filling in the matrix, the impact of each driver on capitalization, payback period and breakeven point of ECH-Earth was estimated.

The estimation results are included in the model (Table 2). This model is based on the Target Tree and is a sequential division of a subgroup of drivers into elements that allow the creation of a weighted link system to estimate the impact of the driver on the resulting indices – capitalization (C), payback period (PBP) and breakeven point (BEP).

In this case, three degrees of influence are taken into account: significant (3 points) – the change in the index from the subgroup of drivers by 10 % increases capitalization by more than 20 %; average (2 points) – the change

Table 1 – Morphological Matrix*

Business area factors		Drivers of business value growth			
		Physical drivers	Cost drivers	Personal drivers	Temporary drivers
Group of factors related to tourism and hospitality	1. Space restrictions				
	1.1. Number of single rooms, "Standard" class, conventional unit	12			
	1.2. Number of single rooms, "Comfort" class, conventional unit	12			
	1.3. Number of double rooms, "Family" class, conventional unit	40			
	1.4. Number of double rooms, "Comfort" class, conventional unit	40			
	1.5. Number of VIP class rooms, conventional unit	5			
	1.6. Number of "Camping" class seats, conventional unit	12			
	2. Financial restrictions on the environment				
	2.1. Accommodation cost, single "Standard", USD		46		
	2.2. Accommodation cost, single "Comfort", USD		62		
	2.3. Accommodation cost, double "Family", USD		77		
	2.4. Accommodation cost, double "Comfort", USD		77		
	2.5. Accommodation cost, VIP, USD		10,000		
	2.6. Accommodation cost, "Camping" class, USD		24		
	3. Operational restrictions on the environment				
	3.1. Number of administrative personnel, people			10	
	3.2. Number of support personnel, people			20	
	3.3. Number of commercial personnel, people			5	
	4. Resource usage restrictions				
	4.1. Number of night stays in a hotel per year, days				255.5
	4.2. Seasonality of demand, %				70
	4.3. Average occupancy rate for the first year, %				50
	4.4. Annual growth rate of hotel visitors, %				14

* These data are provisional and may be specified at the design stage and during further operation.

in the index from the subgroup of drivers by 10 % increases capitalization by no more than 10–20 %; moderate (1 point) – the change in the index from the subgroup of drivers by 10 % increases capitalization by no more than 10 %.

In building the economic model in terms of the impact on capitalization and payback period, an estimation was also made of such groups of factors like those related to the technological effectiveness of creating a closed ecosystem.

According to the results of the current stage of the project, following the formed economic model, the estimation results of the influence of two groups of factors have been received (Table 3). The model sensitivity analysis has been carried out, which reflects the results in case the parameter changes by 10 %.

Tables 2 and 3 show that the groups of temporary and cost drivers have the largest impact on asset capitalization and payback period, and this is particularly evident in the group of factors related to tourism and hospitality.

Table 2 – Estimation results of drivers' impact on capitalization (C), payback period (PBP) and breakeven point (BEP)

A group of factors	Drivers subgroup	Driver impact estimation in points (1 to 3)			Total score in the driver subgroup
		on capitalization (C)	on the payback period (PBP)	on the breakeven point (BEP)	
Group of factors related to tourism and hospitality	Physical drivers	Significant – 3 points	Significant – 3 points	Moderate – 1 point	7
	Cost drivers	Significant – 3 points	Significant – 3 points	Moderate – 1 point	7
	Personal drivers	Moderate – 1 point	Moderate – 1 point	Moderate – 1 point	3
	Temporary drivers	Significant – 3 points	Average – 2 points	Moderate – 1 point	6

Table 3 – Impact estimation of two groups of factors on capitalization (C), payback period (PBP) and breakeven point (BEP)

A group of drivers	Physical drivers			Cost drivers			Personal drivers			Temporary drivers		
	C	PBP	BEP	C	PBP	BEP	C	PBP	BEP	C	PBP	BEP
A group of factors	Capitalization	Payback period	Breakeven point	Capitalization	Payback period	Breakeven point	Capitalization	Payback period	Breakeven point	Capitalization	Payback period	Breakeven point
	Strategic level	Tactical level	Operational level	Strategic level	Tactical level	Operational level	Strategic level	Tactical level	Operational level	Strategic level	Tactical level	Operational level
Group of factors related to tourism and hospitality, %	+24	–8	+1	+33	–10	–2.7	–4	+2	+5	+24	–8	+1
A group of factors related to the technological effectiveness of creating a closed ecosystem, %	–7	+6	+2	–7	+6	+2	–2	+1	+3	+1	+1	–2

In the light of this fact, it can be concluded that in the development of ECH-Earth in the direction related to the hotel and tourism business, it is necessary to reduce the impact of seasonality, increasing the growth rate of ECH-Earth visitors at the project launch stage. Since ECH-Earth is a closed ecosystem, the concept of seasonality can be minimized, and consequently the facility will have significant potential to increase capitalization and reduce its payback period.

The proposed economic model has an applied aspect. For example, it allows drawing conclusions about the impact of sales volume, directly related to the number of rooms, on the capitalization and payback period of the project in the alternative estimation model (Figure 1). It finds its reflection when implementing the business plan, initial requirements to the facility, which can be fixed in the design assignment (Table 4).

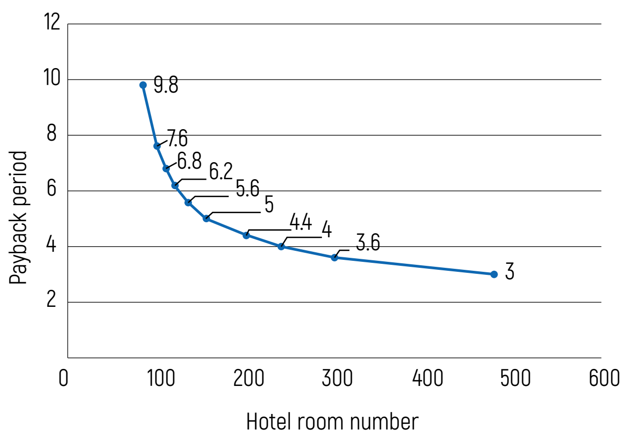

Figure 1 – Diagram of the impact of the number of rooms (from the group of factors related to tourism and hospitality) on the project payback period

In this estimation, when building an economic model, partial consideration is given to the facility belonging to the groups of factors related to the technological effectiveness of creating a closed ecosystem and biosphere. It is important to note that the specification of the model at each stage of its life cycle helps to establish the accuracy of the final cost of the ECH-Earth business and increase its attractiveness for investments in the future

According to the results of the current stage of the project, under the formed economic model, the received results testify to the investment attractiveness of the group of factors related to tourism and hospitality as the basis taken for the construction of the whole economic model.

The tool under development for capitalization management with the help of 3D-model clearly demonstrates the growth of ECH-Earth asset capitalization, allows increasing investment attractiveness for any category of investors, makes the project replicable for different parts of the planet Earth and beyond. The final goal of creating an economic model is to identify 20 key drivers of growth that have the greatest impact on the capitalization and payback period of ECH-Earth investments by ranking and building an optimization model.

When implementing the optimization model to form 20 key drivers, it is planned to use the approach used in the Rubik's cube model, the combinations for the assembly of which can reach up to 88 × 10^{21}. However, there are only "20 steps", called God's algorithm, that allow solving a cube from any state [5].

The view of the model built on the plane is shown in Figure 2.

In this model, each facet represents a group of factors influencing various economic parameters (e.g., capitalization, payback period and breakeven point of ECH-Earth), which characterize the facility investment attractiveness. Three-dimensional model view is shown in Figure 3.

Table 4 – Alternative express estimation of a group of factors related to tourism and hospitality

Sales volume, %	70	80	90	100	110	120	130
Discounted payback period (PBP), years	9.83	7.95	6.89	6.20	5.70	5.33	5.02
Need for investment, USD mln	9.34	9.29	9.24	9.19	9.14	9.09	9.04
Capitalization (C), USD mln	2.58	4.68	6.77	8.86	10.95	13.04	15.12

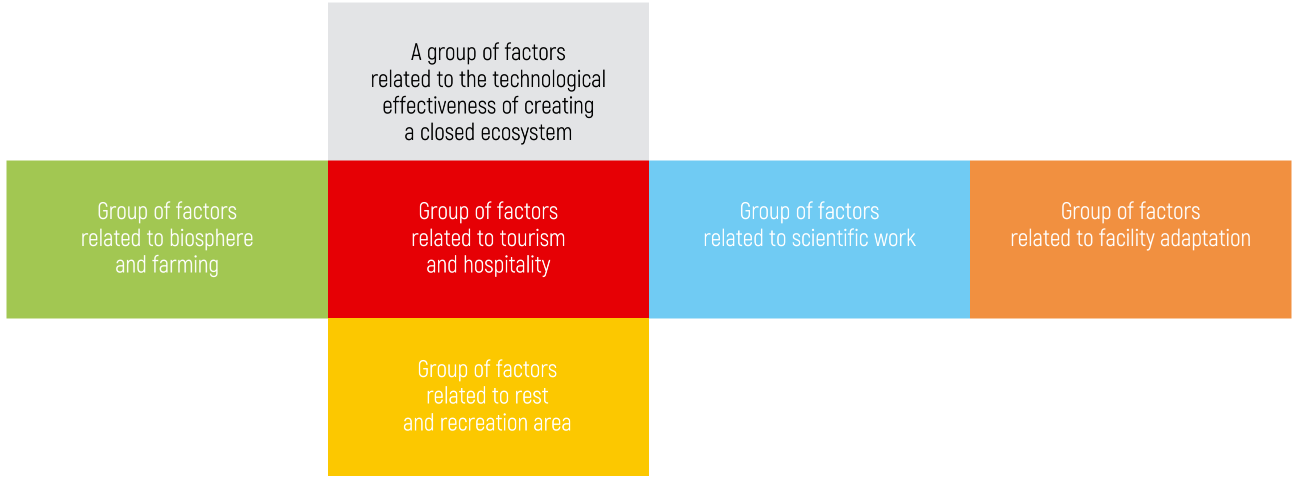

Figure 2 – Economic model of ECH-Earth replication

In the course of the project implementation it is planned to identify and use 3–4 key drivers of capitalization growth for each factor. The display of the given model on a plane gives the chance to pass further on the image of economic model in 3D-volume in the form of a cube (Figure 4).

In the authors' opinion, the idea of ECH-Earth project will be of interest to different categories of people – from scientists and investors to tourists after its construction. For example, those who travel around the territory of the Republic of Belarus will have a rest in the ecologically clean biosphere autonomy and thereby they will take part in the global project.

In addition, the possibility of creating a closed ecosystem of the full cycle, including the possibility of reducing the impact of seasonality, opens up the prospects of using ECH-Earth not only in places of tourist flows, but also in environmentally or climatically unfavorable areas of the planet, such as deserts, tundra, and areas of distinctly continental climate of Siberia, and later on in Earth orbit.

Due to the constructed model of business cost management it will be possible to carry out an estimation of attracted resources efficiency and made decisions, to manage assets effectively, using the integrated approach, and to find the most optimal way of facility cost increase [6].

The approach proposed clearly demonstrates the potential of ECH-Earth replication for an investment purpose and its expansion, that can be implemented through the construction of a similar facility network around the world.

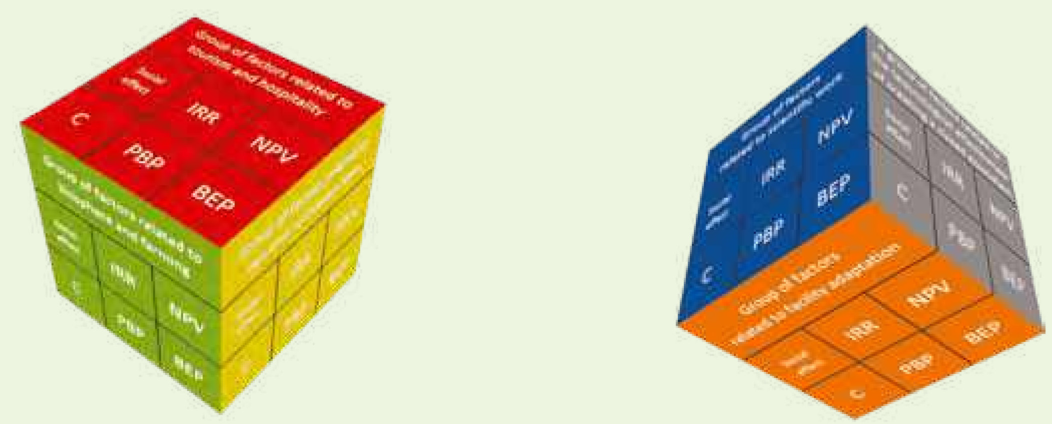

Figure 3 – 3D-model of six main groups of ECH-Earth factors affecting economic parameters

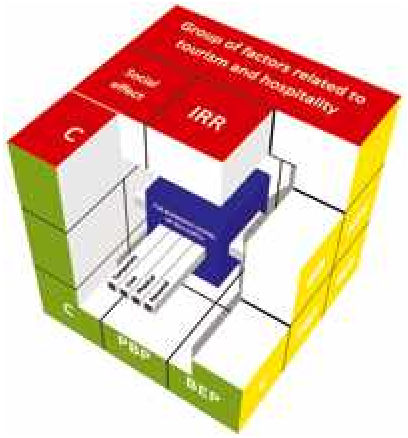

Figure 4 – ECH-Earth replication economic model in 3D

The network structure consisting of ECH-Earth hotels (on all continents, in all countries and in all natural-climatic zones) increases the investment attractiveness of the whole business area. At the same time, the impact of temporary and cost drivers is reduced due to risk diversification and economy of scale, while the use of three key indices (capitalization (C), payback period (PBP) and breakeven point (BEP)) allows estimating the project at the stage of its creation, further implementation at the strategic, tactical and operational levels of management, while combining market, financial and system approaches.

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UDC 624.014; 721.01

Review of possible structural solutions of the EcoCosmoHouse facility on the planet Earth

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A. BONUS (Odessa), N. YERAKHOVETS (Minsk)**

The article considers the options for structural solutions of the EcoCosmoHouse facility on the planet Earth (ECH-Earth), analyzes the existing analogues, identifies the main specifications of the considered closed biosphere volumes. Preliminary calculation of spatial models with applied loads have been carried out in accordance with the norms and regulations for Eurocodes by using the RFEM software. The article also defines the best option from the considered ones and determines the vector of further developments in this field.

Keywords:
EcoCosmoHouse on the planet Earth (ECH-Earth), structural solutions for large span structures, spatial models, autonomous biosphere.

When humanity is on the verge of new discoveries that can fundamentally change the course of history and the vector of development of the entire civilization, and when it is driven by noble goals of saving and improving the life of all living things, no one can remain indifferent and not be impressed by prospects that are likely to be implemented and reasonable in internal engineering design. Such changes are promised by the SpaceWay global space industrialization project designed to solve many modern problems of humanity [1]. It includes the development and construction of the General Planetary Vehicle (GPV) and corresponding Industrial Space Necklace "Orbit" (ISN "Orbit"), as well as the Equatorial Linear City (ELC) and the TransNet Global Network. All these elements are designed to combine technologies, the Earth's biosphere and humans into a synergistic organism, including the establishment of EcoCosmoHouses biosphere clusters (ECHs) adapted to human needs in orbit and on the planet Earth under adverse natural and climatic conditions.

One of the sophisticated problems in development of such residential cluster of a new generation is a creation of the autonomous enclosed biosphere that meets the life support requirements of all living organisms and processes occurring in it, as well as being capable of maintaining a sustainable operation of all systems for an unlimited time period. In order to test solutions, it was proposed to build the EcoCosmoHouse on the planet Earth (ECH-Earth) as a prototype of a space residential cluster with an autonomous biosphere. In this article, the authors consider the features of the load bearing structures of the dome structure that created a single enclosed volume, analyze the selected forms, determine the best option from the proposed ones and approve the vector of further development in the outlined direction.

The distinctive feature of this facility is that apart from the need to close a large span (it was decided that the area of the enclosed biosphere should be at least 2 hectares to recreate various ecosystems – forest, meadow, water, mountain and others – and to complete the experiment in full), the structures and their design should be fitted into the overall extraordinary design of the project. The structures and their exteriors inside the facility should help a person to feel closer to nature rather than create the feeling of being inside a closed greenhouse. An autonomous biosphere, a water system, all components and structures modeled by man inside the projected space (including building structures) should look natural and as close to the environment as possible.

A number of specific requirements are also applied to the facility, the compliance with which is required for integrity of testing. For example, at the first stage of operation of the facility, the dome should consist of translucent structures to ensure survival, growth and development of plants. At the same time, a technical option for closing these windows should be provided too (creation of completely opaque ECH-Earth coverage) in the subsequent period of testing of the biosphere with transition to autonomous internal lighting). This requirement is due to the fact that during the construction in near-Earth orbit, the ECH will make one revolution around the Earth in 1.5 hours, which is too quick for the day and night alternation for living organisms, including humans. However, the absence of translucent structures does not exclude the option of using the Sun as a source of natural light directed by mirrors into the internal space, as well as an energy source for other needs of the space house.

Another condition to ensure the integrity of the experiment is the tightness of the entire facility. This requirement is to be fulfilled with respect to the above-ground part (the dome that covers the biosphere) and to the underground part (heat- and waterproof pit with anti-root protection, containing the ECH-Earth base – sail and water system). All components of the biosphere – air, water, micro- and macro-elements, biological mass, energy and their interaction – should be involved in full circulation inside the enclosed space and provide the self-sufficiency of the entire system. Once again this underlines the importance of the absence of gas-, water- and other interchanges between the internal space of the ECH-Earth and the environment.

Requirements for the entire structures are equally important. They should be resistant to changes in seasonal atmospheric pressure both inside and outside the facility; protect the internal space as much as possible from aggressive external influences (temperature changes, precipitation, biological threats, etc.); be non-flammable, made of environmental friendly materials (that do not emit harmful substances during operation and easily recyclable at the end of life, etc.), durable (protected from oxidation, exposure to light and moisture, destruction by microorganisms). Being in the ECH-Earth should be safe for humans and animals in all respects and at any time period.

When searching for existing analogs of such a facility, the closest object regarding its purpose was Biosphere-2 project built in the Arizona desert of the USA by Space Biosphere Ventures in 1991 [2]. The project purpose was simulation of an enclosed ecological system and identification of human performance for living and working in an enclosed space. However, in this project, the entire volume of the facility with an area of 1.5 hectares was divided into separate enveloped buildings with independent ecosystems. Such an approach initially contradicts to the concept and objectives set by the authors of the article: to create free space, which is the most natural and comfortable for life, a miniature of the Earth's biosphere with the best conditions and parameters taken for humans. There are no partitions on the Earth, neither sharp transitions from one ecosystem to another: climatic zones flow smoothly from one to another, forests, meadows, water reservoirs and mountains complement each other, and their interaction cannot be stopped and limited. That is why the authors of this article have rejected this option as an analogue of a structural solution, as well as their own design option (one of the first space planning options – combination of several geodesic domes (Figure 1)).

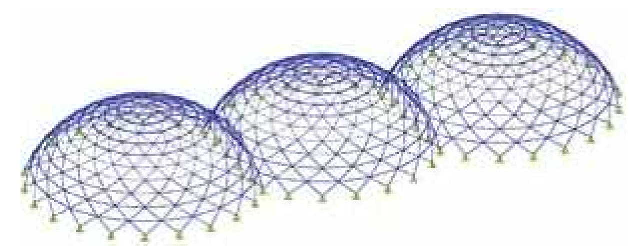

Figure 1 – An option of the structural solution of the ECH-Earth – combined geodesic domes

Further, the existing examples of structural solutions for long span structures of different purposes were considered. For example, the Tropical Island complex in Germany (an airship hangar redesigned into a tropical amusement park, which is the largest self-supporting hall

Biosphere-2, USA

Tropical Island complex, Germany

Seagaia Ocean Dome water park, Japan

"Edem" greenhouse complex, UK

InterContinental Chengdu Global Center hotel, China

National Centre for the Performing Arts, China

"Khan Shatyr" shopping and entertainment center, Kazakhstan

"Hangar One" hangar, USA

in the world – 360 m long, 210 m wide and 107 m high) [3]; the Seagaia Ocean Dome water park in Miyadzaki, Japan (an opening dome with dimensions of 300 × 100 m, where the air temperature does not fall below 30 °C, and water – below 28 °C) [4]; the "Edem" greenhouse complex in the UK (constructed on the site of a former kaolin pit, has tropical and Mediterranean biomes inside (though divided into sections) and uses computerized systems for maintaining the specified parameters of temperature and humidity, rainwater from the pit bottom and energy from wind generators) [5]; the InterContinental Chengdu Global Center hotel near Chengdu, China [6]. To some extent, the prototypes for the designed facility can be the "Khan Shatyr" shopping and entertainment center in Astana, Kazakhstan (the highest tent in the world that is included in the Guinness Book of Records. On its upper floors there is a beach resort with plants and a temperature of 35 °C the year round); the National Centre for the Performing Arts in Beijing, China (more than 3 hectares of space covered with a single dome without columns, half of it is made of glass); the "Hangar One" hangar built in the 1930s to accommodate the "Macon" US military ship (area – 3.2 hectares, height is about 60 m) [7].

All the above mentioned examples have a number of features, construction and operation experience, their assessment can help in the further design of the ECH-Earth. Aspects that one should first pay attention to are as follows: whether the structure fulfills its function; is it durable and cost-effective; is it easy to maintain and repair; are the solutions reasonable from the point of view of economy, power supply, aesthetics and environment.

The main reason for installation of large span structures is the need to use the most of the interior space. As for the ECH-Earth project, the ability to move away from installation of intermediate columns and thus provide space for organization of the internal biosphere is an important criterion when searching for suitable design solutions. One of the first options under consideration was the space of a half cylinder cut along the diameter (width – 120 m, length – 250 m, radius – 60 m) with hemispheres at the ends (Figure 2). A truss with a hinged support was used as the main support structure. All preliminary calculations of special models with applied loads were carried out according to Eurocode standards by using the RFEM software package. Since the final location of the construction site of the facility has not yet been determined, snow and wind loads typical of the Republic of Belarus were adopted.

In order to emphasize that the ECH-Earth is not a separate project, but a part of the global SpaceWay program, the option of creating the space planning of the complex as part of the EcoCosmoHouse, namely, as a torus fragment, has also been analyzed. A torus was considered with a diameter of 400 m (the element diameter – 100 m) with a "hole in a donut" diameter of 200 m. The size of the fragment in plan is 100 m (width) and 250 m (length), a height in the structure center is 50 m, a height at the edges is about 4 m. The space is created by a cross-section of the torus with a plane parallel to the plane that contains its rotation axis at a distance of 150 m from it. An ellipse with a slight truncation at the ends of a large semi-axis is formed in plan (Figures 3, 4). The design concept of this option is a spatial framed structure based on triangular trusses with a height of about 6 m. All trusses are of the same diameter, but each of them is inclined to the side (along the curve contour of the torus outer diameter). To reduce material consumption, an option of the similar solution with a height of 30 m has also been considered (Figure 5).

The next transformation of this solution is substitution of triangular trusses with curved square pipes (Figures 6, 7). The main disadvantage of roofing in the form of a torus fragment is a high horizontal thrust, which is transferred to foundations. To reduce the consumption of materials, it is possible to combine the foundation and rooms of any purpose.

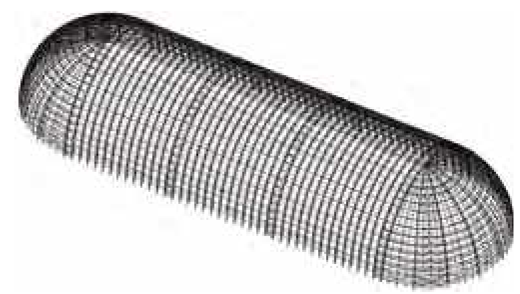

Figure 2 – An option of the structural solution for the ECH-Earth from a half cylinder cut along the diameter with hemispheres at the ends

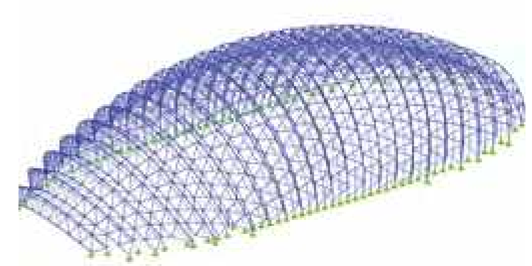

Figure 3 – An option of the structural solution for the ECH-Earth from a torus fragment (height – 50 m)

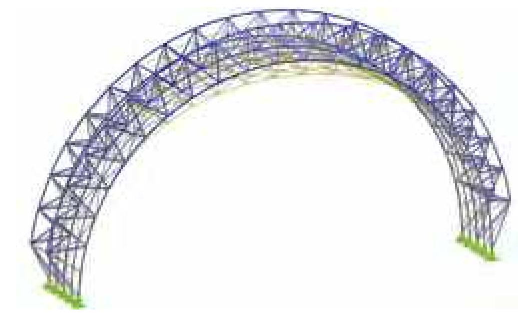

Figure 4 – Operation of the structural solution for the ECH-Earth from a torus fragment with loads applied (height – 50 m)

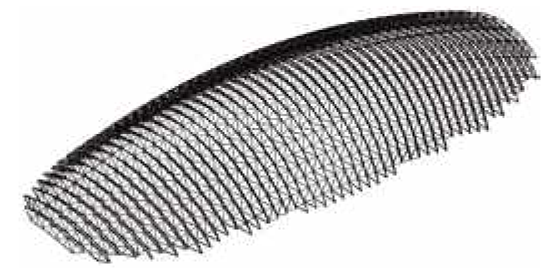

Figure 5 – An option of the structural solution for the ECH-Earth from a torus fragment (height – 30 m)

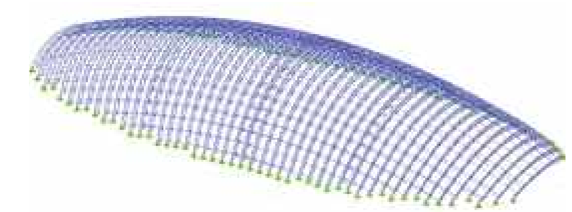

Figure 6 – An option of the structural solution for the ECH-Earth from a torus fragment made of curved square pipes (height – 30 m)

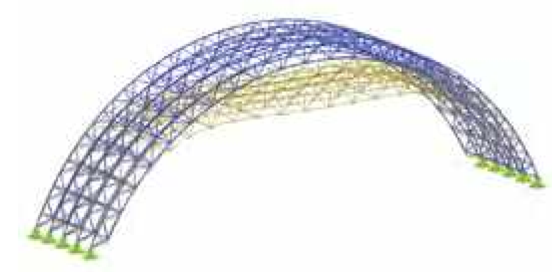

Figure 7 – Operation of the structural solution for the ECH-Earth from a torus fragment made of curved square pipes with loads applied (height – 30 m)

In addition, fundamentally different space planning forms have been considered, such as, pyramids (for example, square in plan (Figures 8, 9) and rectangular in plan (Figures 10, 11)). When choosing a simpler form, the roofing structure of the facility can be significantly simplified. In option with square in plane (150 × 150 m, maximum height – 50 m), in the central part of the pyramid a building comprising of a hotel and greenhouses can be built. The design of this building is a reinforced concrete frame, which will be a support for inclined metal semi-arches. Dimensions of a hotel building/greenhouses – 30 × 30 m, height – 40 m.

However, this solution has a number of structural disadvantages: the basic height is given to a residential/public complex, and not to formation of the biosphere and integration into it; the square shape of the foundation complicates the allocation of separate zones with luxury accommodations, lounge zones, service zones, etc.; there is no "sky overhead" effect, and therefore, compliance with one of the defining requirements – being inside the space should be comfortable for an unlimited time period.

Dimensions of a pyramid rectangular in plan – 100 × 250 m (overall height is about 35 m). Load bearing elements of the roofing are arches made of molded closed profiles. In this option, a hotel building is not tied to the roofing structure and it is much easier to divide the space into zones; but from an aesthetic point of view, the facility definitely loses to more natural forms described earlier, for example, to smooth bends of a torus fragment that looks like a mussel flap.

To develop a natural form, an option, when one half of a torus fragment is raised and the space is covered with glazing, has been analyzed too (Figures 12, 13, 14). The main structural supports in this option are transverse arch-like trusses made of closed mold-welded profiles and central columns on which they rest.

To determine the optimal structural solution for the ECH-Earth, a preliminary comparison of the proposed options was made with respect to the following parameters: area, volume, specific consumption of materials per 1 m^2 of area, specific consumption of materials per 1 m^3 of facility volume, cost of load bearing steel structures (Table 1).

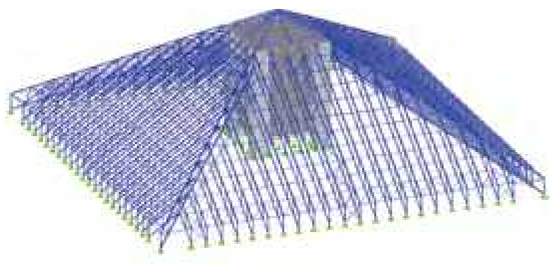

Figure 8 – An option of the structural solution for the ECH-Earth in the form of a pyramid

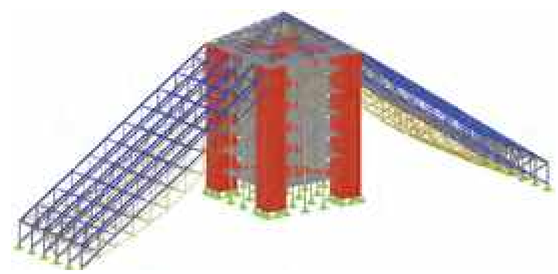

Figure 9 – Operation of the structural solution for the ECH-Earth in the form of a pyramid with loads applied

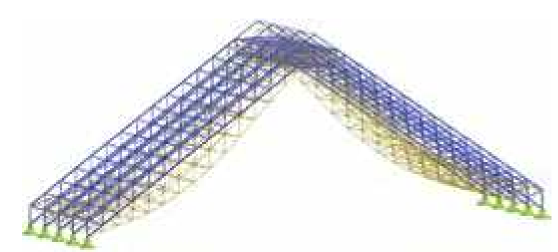

Figure 11 – Operation of the structural solution for the ECH-Earth in the form of a pyramid, rectangular in plan, with loads applied

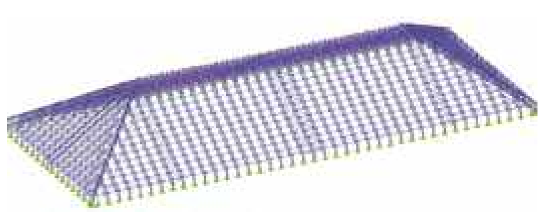

Figure 10 – An option of the structural solution for the ECH-Earth in the form of a pyramid, rectangular in plan

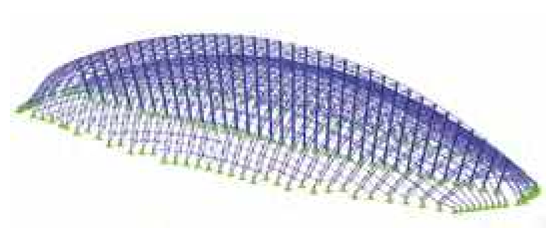

Figure 12 – An option of the structural solution for the ECH-Earth with a raised part of roofing

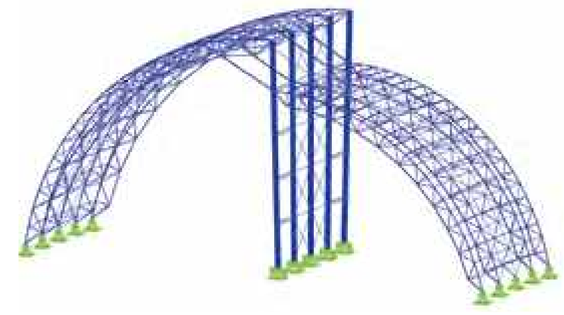

Figure 13 – An option of the structural solution for the ECH-Earth with a raised part of roofing (fragment)

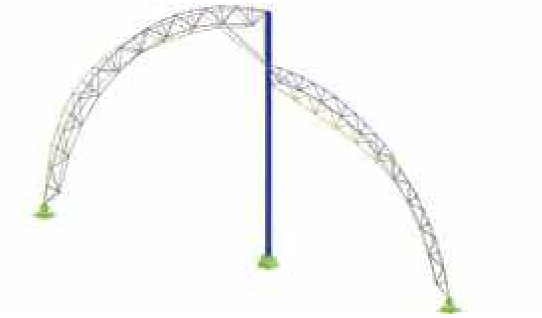

Figure 14 – Operation of the structural solution for the ECH-Earth with a raised part of roofing with loads applied

Table 1 – Comparative analysis of materials consumption and cost of structures (as of May 2019)

PARAMETER	MU	OPTIONS						
		Torus fragment with a height of 50 m (roofing of triangular trusses)	**Torus fragment with a height of 30 m (roofing of triangular trusses)**	**Combined domes**	**Torus fragment with a height of 30 m (roofing of separate trusses)**	**Pyramid (square in plan)**	**Pyramid (rectangular in plan)**	**Torus fragment with longitudinal section**
1. Specific indicators per 1 m^2 of area								
1.1. Steel structures	kg/m^2	81	70	69	60	89	60	78
1.2. Cost of steel structures	BYN/m^2	415	369	360	319	452	305	405
1.3. Roofing	m^2 roofing / m^2 area	1.87	1.5	1.45	1.3	1.36	1.28	1.37
2. Specific indicators per 1 m^3 of building volume								
2.1. Steel structures	kg/m^3	2.8	4.74	3,62	4.11	4.17	3.37	3.33
2.2. Cost of steel structures	BYN/m^3	14.3	25.1	19	21.7	21.2	17.1	17.2
2.3. Roofing	m^2/m^3	0.06	0.1	0.08	0.09	0.06	0.07	0.06
3. Total cost of steel structures	BYN	9,170,626	7,924,961	7,339,670	**6,868,300**	10,169,728	7,627,296	9,305,902
	USD	4,367,098	3,773,906	3,495,188	**3,270,719**	4,842,875	3,632,157	4,431,517

Having analyzed the Table, we can conclude: the most feasible option is a torus fragment with a height of 30 m with trusses made of molded square pipes. This is one of the most aesthetic and nature-like forms of all considered (Figure 15).

A torus fragment with a longitudinal section and a risen part of roofing is also aesthetically attractive (Figure 16). However, since the height of a building increases, the consumption of materials and the cost of load bearing structures are significantly increased.

These findings are not the final ones. They allow us to choose the further vector of development and decide on the next steps. For example, further calculating the cost of installation of foundations could change the priority of options with respect to the cost-effectiveness rating. The occurrence of new options is also under consideration (for example, with a flat roofing or terraces, the area of which can be allocated for public areas and greens, etc.). To obtain objective figures, it is necessary to perform a comprehensive analysis, when comparing not separate elements of the system with each other, but the entire packages of solutions, which will be possible with a detailed study of all components of the ECH-Earth. Thus, it is very important to take into account all the requirements for the facility, to recognize and demonstrate the necessary flexibility and innovativeness of approaches in the rapidly developing world, as well as to realize the responsibility and prospects of the project in global programs on space exploration and human civilization salvage.

Figure 15 – Rendering of the ECH-Earth (option) with a structural solution in the form of a torus fragment (height – 30 m)

Figure 16 – Rendering of the ECH-Earth (option) with a structural solution in the form of a torus fragment with a longitudinal section and a risen part of roofing

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UDC 579.65

Soil and soil microorganisms in EcoCosmoHouse biosphere

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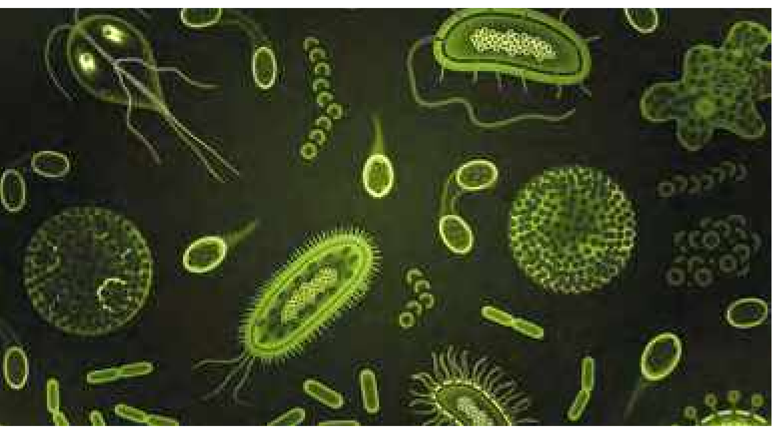
The article provides information about the diversity of soil microorganisms and their role in soil formation and fertility. The authors have singled out from natural sources (soil, brown coal, biohumus) 18 associations of agronomically valuable microorganisms (more than a thousand species) of the following ecological-trophic groups: ammonifying, oligotrophic, nitrogen-fixing, cellulose-decomposing, phosphate-solubilizing, etc. Based on the selected microbial cultures and brown coal crushed with electrohydraulic method, we have created fertile soil and optimized its composition providing a plant with all the necessary nutrition.

Keywords:
soil, soil microorganisms, brown coal, humic substances.

Soil is a key component of the Earth's biosphere, since together with soil microorganisms it forms many important processes occurring in it, and first of all circulation of biogenic elements.

Soil is one of the most favorable and permanent habitats of microorganisms. Their number in 1 g of soil is estimated in millions and billions of cells. Soil can be considered as a bank in which the most diverse types of microorganisms are stored, or as the gene pool of the microworld. [1]. The world of soil microorganisms is very diverse. It includes bacteria, actinomycetes, fungi, algae and protozoa that perform important ecological functions through the successive replacement of one microbial community with another.

While studying the ecology of soil microorganisms, the famous Belarusian scientist O. Kolleshko has quite comprehensively characterized their importance for the ecosystem [2]. Microorganisms participate in mineralization of plant and animal residues, carry out circulation of substances and energy, replenish the nitrogen reserve of soil through biological nitrogen fixation, solubilize phosphorus from organic and poorly soluble inorganic compounds,



enrich soil with biologically active compounds (enzymes, amino acids, auxins, vitamins, etc.) and antibiotic substances that inhibit the development of phytopathogens. Mushrooms, actinomycetes, capsular bacteria, earthworms are involved in the formation of a solid lumpy structure that improves the air-and-water regime of soil. Thus, the huge role of soil microorganisms in soil formation, maintenance of fertility, optimization of plant nutrition, as well as in geochemical processes in the biosphere is obvious.

To date, the acute problem is the anthropogenic impact on the soil. Excessive use of chemical fertilizers and pesticides violates soil fertility changing the composition of soil microflora and its activity. This leads to degradation of arable land. The use of agrobiotechnologies in agricultural practice, including the use of active strains of microorganisms that have a range of useful properties, is an alternative method to raise soil fertility, increase crop yields and obtain environmentally safe products.

In this regard, the purpose of our research was to create the optimal structure of the microbial cenosis of soil under EcoCosmoHouse (ECH) [3] conditions including all the necessary diversity and number of microorganisms, similar to the composition of fertile soil, which consists of natural humus and various types of soil microorganisms participating at all levels of circulation of substances.

Agronomically valuable soil microorganisms were singled out from soil samples not involved in agro-industrial production, selected in various regions of Belarus, Russia and Ukraine, as well as from biohumus aged for six months, sand from the United Arab Emirates and samples of brown coal from the Brinevskoye deposit (Belarus) in the laboratory of agrotechnical research at SkyWay Technologies Co. Soil sampling was carried out by the envelope method (average sample from five points) in sterile plastic bags. Identification of the main ecological-trophic groups was carried out by planting in agar medium: for amylolytic bacteria and actinomycetes - in a starch-ammonia medium, for oligotrophic – in Ashby medium, for cellulose-decomposing – in Imshenetsky medium, for ammonifying bacteria – in meat-and-peptone agar, for phosphate-solubilizing bacteria – in Muromtsev medium [4]. The selection of destructor-bacteria of brown coal was carried out in a medium where crushed brown coal was used as the sole source of carbon and nitrogen in a concentration of 0.01 % in terms of dry matter [5]. The use of brown coal by microorganisms was evaluated by a decrease in the intensity of the medium color with the addition of glucose and in the absence of carbohydrates, as well as by a change in the number of colony forming units (CFU). The study of the viability preservation by selected associations of microorganisms introduced into the soil on the basis of crushed brown coal was carried out by sowing in agar nutrient media for three months.

The phytotoxicity of the selected associations of microorganisms was tested on the seeds of watercress as the most sensitive culture for inoculation.

The effectiveness in the use of selected associations of soil microorganisms was established under conditions of a photo-room during inoculation of green crops (Lollo Ross lettuce and arugula) at the scientific and technical base of Unitsky's Farm Enterprise (Republic of Belarus).

The total number of microorganisms in samples of brown coal was about 10^7 CFU per 1 g. There were separated two associations of microorganisms with destructive activity in relation to brown coal and the ability to transform humic substances. While studying the ability of the microorganisms under examination to use humic substances of brown coal (within one month), we have observed a microbial decomposition of the latter, leading to turbidity of the medium and a decrease in its color intensity. Discoloration was stronger in flasks with medium containing an additional 0.01 % of glucose (Figure 1).

The data obtained indicate that decomposition of humic substances occurs more intensively in the presence of glucose, that is, under conditions of cometabolism.

The study of the dynamics in the number of microorganisms-destructors of brown coal during cultivation in the medium with crushed brown coal as the sole source of carbon and nitrogen showed an increase in their concentration by an average of an order of magnitude (10^9 CFU/ml) on the 10^{th} day of cultivation, which confirms the ability of the selected bacteria to develop in this medium.

Eighteen associations of aerobic and anaerobic microorganisms of various agronomically valuable groups: ammonifying, oligonitrophilic, including nitrogen-fixing, cellulolytic (mesophiles and thermophiles), phosphate-solubilizing, as well as those using mineral forms of nitrogen were singled

Figure 1 – The ability of selected associations of brown coal microorganisms to use humic substances:
1 – association No. 1, cultivated on the medium with brown coal (0.01 %);
2 – association No. 1 (0.01 % of brown coal and 0.01 % of glucose);
3 – association No. 2 (0.01 % of brown coal);
4 – association No. 2 (0.01 % of brown coal and 0.01 % of glucose);
5 – control 1 (medium with 0.01 % of brown coal);
6 – control 2 (medium with 0.01 % of brown coal and 0.01 % of glucose)

out from soil samples not involved in agro-industrial production, as well as from sand and biohumus sample.

Testing of the identified associations of microorganisms for phytotoxicity showed that inoculation of watercress with bacterial cultures had a stimulating effect on seed germination, increasing their sprouting and germination energy. The increase in phytomass in variants with seed inoculation was 26–71 % compared with the untreated option. The maximum

increase in phytomass was observed during seed inoculation by the association of oligonitrophilic bacteria, which is explained by the nitrogen-fixing ability of the latter, since nitrogen is an extremely important element at the initial stage of plant growth and development. An additional positive property of nitrogen-fixing bacteria that stimulates seed germination is the synthesis of phytohormones (auxins, etc.).

Based on the microbial associations we have identified, a bank of microorganisms has been created, containing more than a thousand species, which is of interest for various purposes of microbiology and biotechnology (Figure 2).

Figure 2 – Bank of agronomically valuable groups of microorganisms

Associations of soil microorganisms, including all the necessary diversity and number of bacterial cultures, extracted from natural sources of various soil-climatic zones and performing important ecological functions, were used by us to create a soil similar in composition to fertile. To do this, we used brown coal crushed using electro-hydraulic method (Bolshesyrskoe deposit, Krasnoyarsk region, Russia), used as a carrier and nutrient medium for introduced microorganisms, with the addition of ash as a source of microelements. Ash was obtained by burning brown coal from the same deposit. Electro-hydraulic effects destroy the molecules of humic substances, and they become more accessible for consumption by microorganisms. Technological scheme of soil production is presented in Figure 3.

The survival capability of associations of microorganisms on the developed soil was studied for three months. The change in the number of microbial introduced species during their storage in the soil was insignificant. By the end of the third month of storage, the concentration of microorganisms was not less than 2.5×10^9 CFU/g of soil. This indicates that the introduced microbial cultures are able to exist there for a long time.

Checking of the effectiveness of the developed soil under model conditions in the light-house showed an increase in the phytomass of plants of the studied lettuce crops (150–200 %) compared with a substrate based on sand

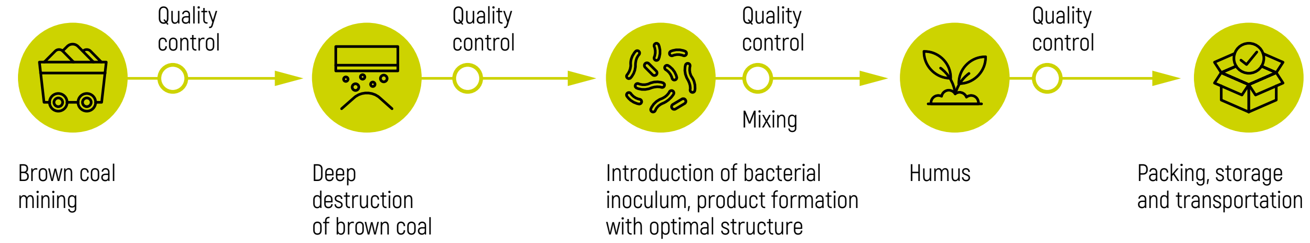
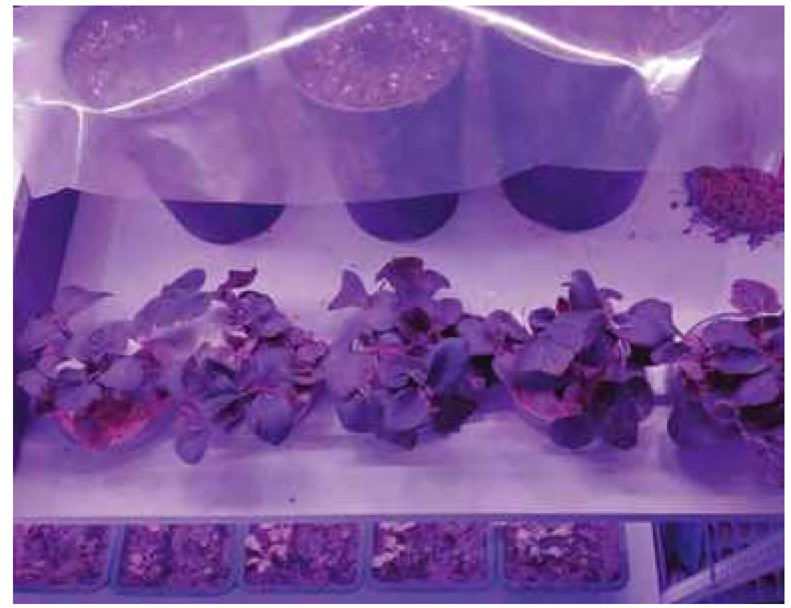


Figure 3 – Technology of obtaining soil (humus)



and peat (2 : 1). To confirm the effectiveness obtained in cultivation of plants in laboratory conditions in the developed soil, a field experiment on winter triticale is started.

Thus, the selected associations of microorganisms and the soil developed on their basis accelerate the growth and development of plants by supplying them with all the necessary nutrients and natural growth regulators.

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UDC 551.581.2

Systems for maintaining optimal climatic parameters of EcoCosmoHouse on the planet Earth

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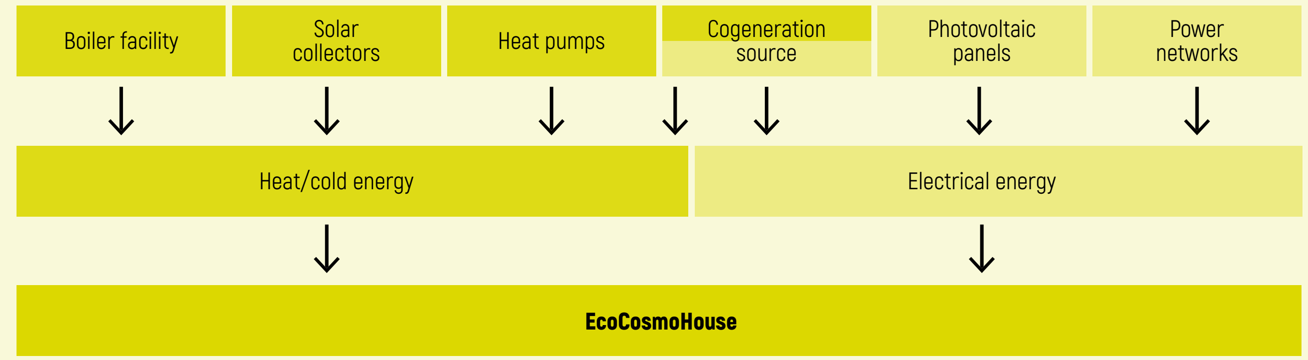
The article discusses the main problems of ensuring optimal climatic parameters within EcoCosmoHouse on the planet Earth (ECH-Earth); describes the results of preliminary calculations of some basic parameters, such as temperature, relative humidity and pressure; indicates direction for further research.

Keywords:
EcoCosmoHouse (ECH), closed ecosystem, optimal climatic parameters, heat supply systems, thermal protection of a building, transpiration.



One of the key problems to create a closed ecosystem, in particular EcoCosmoHouse on the planet Earth (ECH-Earth) [1], is to maintain specified optimal climatic parameters, such as temperature, relative humidity and pressure, with the lowest economic costs. Let us deal with the issues of maintaining each of these parameters in more detail.

The first task of maintaining climatic parameters is to ensure the required air temperature inside the ECH-Earth. For the accepted climatic zone (northern subtropics), the range of air temperatures in the cubature of ECH-Earth is 15–25 °C, therefore the following fact is obvious – even under conditions of ideal thermal insulation in Belarus, an external supply of thermal energy is necessary (the average annual air temperature for the Republic of Belarus is 6.1 °C).

From the point of view of the ECH-Earth concept, the most suitable external source of energy is the Sun due to its inexhaustibility and free-of-charge basis. However, for example, for the Republic of Belarus, the ratio of the average output power of solar panels to the rated one is approximately 1 : 10 [2]. In this regard, the Sun as a source cannot be considered an unambiguous solution to the problem of heat supply, therefore it is necessary to consider other options, the simplest of which is a boiler house operating on natural gas. The bottleneck of this source is the environmental constraints of the construction site, as well as the cost of heat supplied, which directly depends on the tariffs for natural gas. For Belarus, they are constantly changing and largely depend on the procedure for determining domestic Russian gas prices and on the political relations between Belarus and Russia. Thus, the price of gas for Belarus can change both in a positive and negative directions [3]. Also noteworthy is the option of heating with the use of heat pump plants, currently requiring significant investments, but at the same time having a very high energy efficiency. The variant of heat supply is also possible using a combined (with the generation of electric and thermal energy) source based on the technology of brown coal gasification. However, the most advantageous is the optimal combination of different types of sources, allowing to minimize operational expenses and optimize capital costs. The ratio of sources depends directly on the ECH-Earth location. For example, when placed on the Arabian Peninsula, solar energy will prevail, and when placed near coal deposits, it will be the technology of coal gasification.

The arrangement of the internal heating system is also a non-trivial task. To reduce the load on the external source, and consequently, reduce capital and operating costs, a high degree of thermal protection of the building is necessary. One of the options is adding thermal insulation of a building. The minimum allowable value of the heat transmission resistance is selected based on the condition of non-condensation on the enclosing structures, which means that the temperature of the inner surface of the ECH-Earth should not fall below the dew point temperature of the air. The maximum value is limited by economic factors, such as lower operating costs per unit of thermal insulation to be added, taking into account the investment in this additional layer. The accepted insulation material should meet the required characteristics in terms of cost, environmental friendliness, manufacturability, flammability and a number of other indicators.

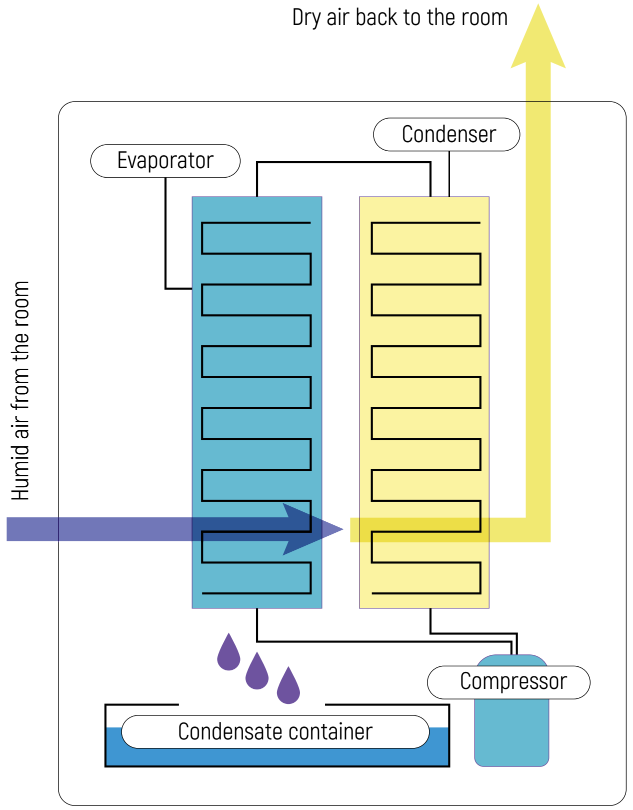
When choosing directly the placement options for heating devices, one should take into account the features of heating up of large-volume structures. When air is heated directly, the convective transfer of warmer flows to the upper layers of the inner "atmosphere" can cause the lower layers to remain cold, not to mention the warming up of the soil itself to the required temperature. In this case, there will also be an aesthetic problem of placing heaters in the central parts of ECH-Earth in order to provide a more uniform heating. In this regard, it is obvious that it is necessary to heat up the soil, from which air will be warmed by heat transmission. Such a mechanism of heat exchange is natural, because initially the sun warms the soil, and then the soil heats the air. However, in order to avoid overheating of the soil, an additional "classical" method of heating the air is also required – radiators and convectors.

Based on the above, it is reasonable to note that the issue of arranging the heat supply system and thermal protection of the ECH-Earth building should be treated competently, based on a whole range of parameters: economic, technical and environmental.

To maintain the required relative humidity, it is necessary to understand primarily the mechanism of its increase. Taking into account the fact that any system tends to a state of equilibrium, in the presence of water in the liquid phase (for example, in the presence of water bodies), its constant evaporation will occur and, as a result, the relative humidity will increase. Air humidity will also increase due to the

transpiration phenomenon (the process of water movement through a plant and its evaporation through the external organs of the plant, such as leaves, stems and flowers) [4]. So, to maintain humidity, it is necessary to condense the moisture that has penetrated into the air. Physically, this is accomplished by cooling the air, technically – using dehumidifiers or ventilation. The second option is excluded, because it contradicts to the concept of a closed ecosystem.

When deploying mechanisms to maintain humidity, formation of a large amount of condensate is inevitable. According to preliminary estimates, about 10 tons of water will be released per day only from the surface of water bodies in the ECH-Earth. Evaluation of the amount of moisture that enters the air through transpiration, and will later be condensed, should be based on the composition of the plants and the characteristics of their vital activity. Water obtained in dryers can be used after minimal cleaning for drinking purposes, as well as for watering plants. These processes will become part of water circulation in a closed ECH-Earth system. In accordance with a similar scheme, drinking water supply was carried out in Biosphere-2 [5].



Condensing air dryer

No less important is pressure. Most people react negatively to changes in atmospheric pressure, which also changes blood pressure. A rapid decrease in atmospheric pressure leads to oxygen starvation of tissues (primarily the whole brain) [6].

According to Mendeleev – Clapeyron equation, pressure is directly proportional to temperature [7], from which it follows that a rise or fall in temperature inside the ECH-Earth causes a regular change in pressure. With the action of daily temperature fluctuations (day-night) there will be regular pressure fluctuations. Calculations show that when the daily temperature of ECH-Earth fluctuates in the range of 19–25 °C, the pressure fluctuations will be 757–773 mm of mercury. Annual fluctuations will be in the range of 747–773 mm of mercury. In case of the negative impact of such a range of differences on living organisms, it will be necessary to equalize the change in pressure by means of a compensating volume. As an option, it is possible to reduce the range of temperature variation to ensure the allowable range of variation of atmospheric pressure inside the ECH, which should be close to the external pressure, since the pressure difference per mm of mercury will produce an additional load on ECH shell in the amount of about 13 kg/m^2. For example, a difference of 20 mm of mercury pressures inside the ECH and outside will load the hermetic enclosure of the structure stronger than snow or wind load – above 260 kg/m^2.

The fact is obvious that maintenance of optimal climatic parameters, as well as the implementation of other EcoCosmoHouse systems, are extremely complex tasks. This statement is supported by attempts to create closed ecosystems in the past. A striking example is Biosphere-2 – a highly technological structure for its time, but which did not achieve the desired result due to the fact that factors that may seem insignificant at first glance, but which are capable of provoking a chain destruction reaction of the entire ecosystem, were not taken into account. Further studies of climate maintenance systems should be aimed at determining the technical feasibility of the measures described, as well as at determining the technical, economic and environmental indicators.

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UDC 58.006; 58.01.07

Plants of special purpose and their use in EcoCosmoHouse

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The article reviews the main classes of plants suitable for growing under EcoCosmoHouse (ECH) conditions and used as a substitute for traditional household chemicals, cosmetics, antimicrobial agents, etc. The results of the experimental part of the work are presented, during which phytoncide extracts of conifers and soap samples of soap nuts were obtained.

Keywords:
EcoCosmoHouse (ECH), special purpose plants, phytoncide, soap nuts, household chemicals.

Currently, selection of plants and methods of their use in various fields are very relevant for EcoCosmoHouse (ECH) as a confined biosphere, for example, to replace traditional household chemicals, cosmetics, antimicrobial agents, etc. Special purpose plants can be used as an alternative material – soap, dyeing, insect-eating, phytoncide-containing, etc. The term "special purpose plants" means the most suitable types of plants with useful properties [1].

Let us consider in more detail the main classes of plants taking into account the conditions of their growth in the ECH. Historically, the first detergent was water. However, when water did not help, people used saltpeter, ash, sawdust, egg yolks, etc. In many countries, "soap" plants were used for washing the body and clothes due to special substances contained in them – saponins (from Latin *sapo* – soap) [2].

Saponins are usually found in plants in dissolved form in the cell fluid of almost all organs. The number of saponins varies widely. Table 1 lists the plants that have saponins [3].

One of the most common plants is *Saponária officinális* ("soap grass", "red soap root", "dog soap"). When rubbing the roots (especially pre-dried and crushed) with hot water, there appears a lush foam that does not subside for a long time. The content of saponin in *Saponária* is up to 32 %.

In addition to *Saponária officinális*, soap nuts are widely known – the fruits of a soap tree (up to 40 % of saponins) [4].

Table 1 – Plants containing saponins

Plant	Family	Plant material
Aralia mandshúrica	Araliaceae	Roots
Astragálus dasyánthus	Fabaceae	Shoot system
Dioscoréa caucásica	Dioscoreaceae	Root system
Dioscoréa nippónica	Dioscoreaceae	Root system
Panax ginseng	Araliaceae	Roots
Oplopánax elátus	Araliaceae	Root system
Rhapónticum carthamoides	Asteráceae	Root system
Glycyrrhiza glábra	Fabaceae	Roots
Glycyrrhiza uralensis	Fabaceae	Roots
Tríbulus terréstris	Zygophylláceae	Shoot system
Saponária officinális	Caryophylláceae	Roots
Adōnis vernālis	Ranunculaceae	Shoot system
Siléne vulgáris	Caryophylláceae	Shoot system

Aqueous solutions of soap nuts have a number of useful properties, such as antibacterial, anti-inflammatory, emollient, nutrient, moisturizing, whitening.

Under ECH conditions, it is advisable to grow soap trees, since their fruits can be used for washing in their pure form (replacing detergents and household chemicals) or in the form of a powder based on soap nuts. Soap trees grow well on loamy soil and do not require special care.

Another useful plant species suitable for cultivation in ECH is dyeing plants containing dyes (pigments) in their organs and tissues (leaves, roots, stems, fruits, flowers, seeds) used for the production of dyes. Dyeing plants were among the first that people began to use for dyeing fabrics: processed in this way, they did not fade in the sun, did not lose color, were safe for human health [5].

Currently, due to the expansion of the production of synthetic aniline dyes, vegetable dyes are used only in the traditional and silk industries. Turmeric, henna, madder, marigold, barberry, pomegranate, etc. are among the most famous plants of this class. Under ECH conditions, dyeing plants can be used to dye not only textiles, paper, wood, but also oil, cheese, rice, bakery products.

In our opinion, interesting in terms of use in ECH are insectivorous plants that can catch and digest insects and small animals. There are about 500 species of such plants. They mainly grow in places with high humidity; they compensate nitrogen deficiency with caught and digested victims. The most common species are the sundew, Venus flytrap, butterwort, sarracenia. These plants are suitable for breeding under ECH conditions and in addition to catching insects can perform a decorative function [6].

Some of the most important plants with a wide application value are plants rich in phytoncides, substances of plant origin that have the property to slow down the growth of microorganisms and, in some cases, to kill them. Phytoncides include certain essential oils. Phytoncides provide the natural immunity of plants, serve as growth and development regulators, participate in the processes of respiration and thermoregulation. The main representatives of the class of plants containing the maximum amount of phytoncides are pine, silver-fir, spruce, oak, poplar, onion, garlic, horseradish, mustard, etc. These plants, which also affect the composition of the atmosphere, are suitable for growing under ECH conditions. Recovery of phytoncides from raw materials can occur, for example, by extraction [7].

Among special purpose plants, phytofilters occupy an important place. They are capable of absorbing harmful substances from the air, dust, and electromagnetic radiation. Currently, there is a whole direction – phytodesign,

which takes into account the positive influence of plants on humans. The most famous flower – aloe – is able to purify the air of formaldehyde. *Hedera helix* absorbs up to 90 % of benzol. *Maranta leuconeura* arrowroot absorbs ammonia and helps to humidify the air. These properties are very important in ECH conditions [8].

For ECH, sweetener plants are of interest. The plants of this group - stevia, Jerusalem artichoke, licorice, etc. [9] – contain natural sugars that are more beneficial and less caloric than sugar from sugar beets.

Plants can be effectively used as a substitute for many products of the chemical industry. The production of valuable products from vegetable raw materials does not require complex hardware design and does not pollute ECH. Table 2 shows the calculations on necessary costs and ECH areas for each of the plant species.

Based on the above, it is of interest that the authors of the article studied several representatives of special-purpose plants, assessed and visualized their useful properties in the framework of ECH project.

Objects of study: samples of plant material (pine and spruce needles), soap nuts *S. Mukorossi*, *S. Trifoliatus*.

Table 2 – Calculation of the number of special purpose plants to provide ECH with required products of natural origin

Description of product	Consumption rate of plant products per month per person, kg	Quantity of products per month to feed 100 people, kg	Quantity of products obtained from one plant per month, kg	Number of plants, pieces	Occupied area, m²
1. Plants - detergents (soap nuts *Sapindus Mukorossi, Sapindus Trifoliatus*)	1	100	5	20	200
2. Dyeing plants (turmeric, henna, madder, marigold, barberry, pomegranate, etc.)	0.05	5	0.1	50	100
3. Insectivorous plants	Not consumed	Not consumed	Not consumed	50	5
4. Plants rich in phytoncides	Not consumed	Not consumed	1	100	200
5. Phyto-filter plants	Not consumed	Not consumed	Not consumed	100	10
6. Sweetener plants (in terms of stevia)	0.6	60	0.025	2,400	500

Experimental part

1. For extraction of essential oils, samples of pine and spruce needles, pre-fine-cut in a knife grinder up to a length of 3–6 mm, were mixed with ethyl alcohol and water in mass ratios in terms of dry matter 3 : 1; 2 : 1; 1 : 1; 1 : 2; 1 : 3; 1 : 4; 1 : 5 and left in a closed container for 7–10 days to obtain a concentrated infusion.

2. For production of detergents, soap nuts were soaked in water for a day in the ratio of 3 : 4 by weight. The resulting mixture was processed in two different ways, depending on the desired final product.

2.1. To obtain a detergent powder, the mixture created in step 2 was ground without addition of water. At the same time, the formed thick foam was dried in a layer of 1–3 cm at 40 °C temperature for 24 hours and ground until a powder with a particle size of 0–2 mm appeared.

2.2. To obtain liquid soap, two parts of water were added to one part of a mixture of soap nuts and water. Then the mixture was ground in a knife grinder at minimum speed for a long time. The resulting dark brown suspension was filtered, the filtrate was evaporated to a viscous solution containing 15–20 % of saponins by weight.

Results

Coniferous essential oils are natural phytoncides with the strongest properties. In the course of the work, the optimal way of extracting coniferous oils from natural raw materials – spruce and pine needles – by distillation was chosen. Figure 1 shows coniferous extracts obtained with different ratios of raw materials to alcohol. It is defined that the ratio of raw materials to alcohol should be 3 : 1 to obtain the maximum yield of essential oil, however, at a ratio of 2: 1 and 3 : 1, the product yield is almost identical. The degree of extraction is significantly less in the aquatic environment than in alcohol. Infusion time is at least 10 days. The degree of raw material grinding also has a significant effect (optimally – the maximum possible).

Figure 1 – Alcohol coniferous extracts of phytoncides

Alcohol infusion

The most concentrated sample was created at a ratio of needles to ethyl alcohol 3 : 1, however, difficulties arose in recovering the extract by pressing. The ratio of needles to alcohol 2 : 1 is preferable from the point of view of technological effectiveness of obtaining an infusion during extraction with ethyl alcohol. In this case, a concentrated extract is formed, which can be separated from vegetable raw materials without serious losses. It was easiest to recover extract at a ratio of needles to ethyl alcohol 1 : 5, but at the same time it has a low concentration of active substances.

The obtained essential oils are proposed to be used for cosmetic purposes by applying to the skin (by pipette) or in the form of ice coniferous cubes.

As a result of grinding soap nuts (depending on the degree and method of grinding), two types of product were made suitable for use – liquid soap and powder obtained by drying the foam.

Liquid soap can be used independently as a detergent or personal hygiene product. Powder created by drying the emulsion can be formed in bars or used without further processing. Both products foam well, have a characteristic smell of soap nuts. The washing ability of these samples is quite high, which makes it possible to introduce natural flavors, dyes and biologically active substances into these products to obtain products with the desired properties.

a)

b)

c)

Figure 2 – Products derived from soap nuts:
a – detergent (liquid soap); b – powder; c – emulsion

Thus, the research presented the results regarding the study of the main classes of special-purpose plants, which can be useful for ECH conditions by their properties. It has been established that the optimal ratio for obtaining coniferous extracts from phytoncide plants is a raw material: alcohol 2 : 1.

Extraction of phytoncides is more reasonable to do with 96 % alcohol, as this provides a higher rate and completeness of extraction. Compared to extracts with a low alcohol content, the extract of phytoncides thus formed evaporates more intensively. As a source for the production of alcohol by the total of indicators (% of alcohol yield, area occupied by plants), potatoes are best suited. From 1 kg of starch by fermentation, taking into account losses, 0.675 l of 96 % alcohol is released. The starch content in potatoes is 14–25 % for highly starchy varieties (Elizaveta, Skarb, Red Scarlet, etc.). In this case, 0.095–0.169 l of 96 % alcohol or 0.228–0.406 l of 40 % for other uses will be obtained from 1 kg of raw material. Based on experimental data, about 1.05 l of 96 % alcohol and 0.25 kg of needles are needed to produce 1 l of phytoncide extract. Accordingly, 5.9–10.5 kg of potatoes will need to be processed to obtain 1 l of phytoncide extract.

Emulsion and powder suitable for use as a substitute for traditional detergents are created from soap nuts.

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UDC 574.685; 574.682

Use of chlorella for oxygen production and wastewater treatment in closed ecosystems

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The paper discusses the concept of oxygen production in EcoCosmoHouse based on the use of chlorella microalgae, indicates the appropriate approaches to its cultivation for this purpose. A description is given of the introduction of sewage into chlorella cultivators as an element of the nutrient medium. The latter can serve as a water purification mechanism in a closed ecosystem.

Keywords:
Chlorella culture, suspension, water purification, organic waste processing, oxygen production, gas exchange, chlorella, EcoCosmoHouse (ECH).

The space industry has long paid attention to Chlorella as a plant organism with many universal properties: it takes up little space, is an oxygen generator and a completely edible biomass containing almost all the substances necessary for the human body. Many experiments have convincingly shown that while implementing space megaprojects, it is convenient to use chlorella as a source of oxygen and water. Recently, another very valuable ability for astronautics was discovered in it – the ability to clean atmosphere from harmful impurities [1].

One of such megaprojects in near-Earth orbit, ready to be implemented in the coming decades, is the SpaceWay program developed by engineer A. Unitsky. Its integral part are the biospheric EcoCosmoHouse (ECH), for which chlorella can become a kind of "oxygen cushion" [2]. In this regard, the authors see the objectives of this paper as the study of the possibilities of using chlorella in the generation of oxygen and wastewater treatment, as well as the development of conceptual solutions related to these processes.

Chlorella is a unicellular green alga that can manifest itself as both an autotrophic and heterotrophic organism [3]. Of particular interest is the biochemical composition of chlorella (Figure 1), which includes not only a specific set of vitamins and minerals, but also has a high protein content, which determines the nutritional value of the corresponding product (the richest composition of biologically active substances) [4]. In this regard, chlorella is of great economic importance. In particular, this alga can be used as an additive to food [5, 6] and feed in animal husbandry [3], and the suspension of chlorella – for soil fertilization [7].

In addition, the potential of chlorella for the production of oxygen and wastewater treatment in closed ecosystems is of fundamental interest. To date, there is already some experience with similar use of chlorella in the framework of project BIOS-3 [8, 9].

The general scheme of waste management in EcoCosmoHouse (ECH) is a binary system (Figure 2) for processing of solid and liquid fractions.

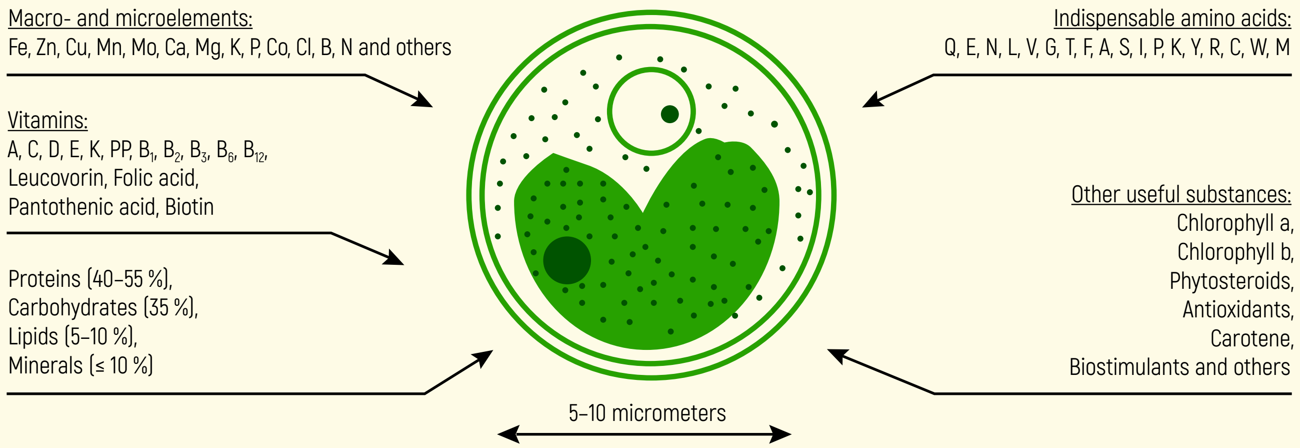


Figure 1 – Biochemical composition of chlorella

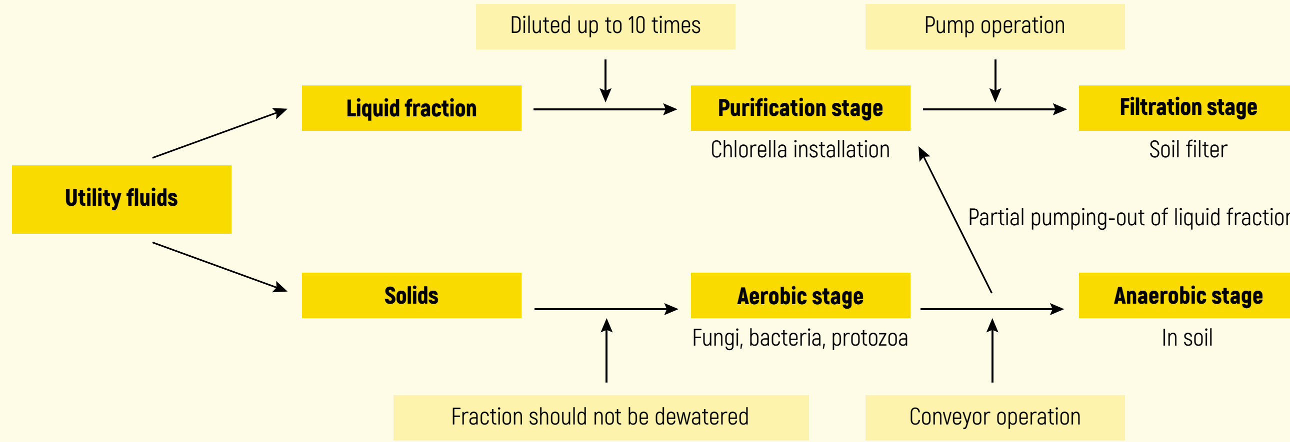


Figure 2 – Waste management concept scheme

At the same time, a significant part of the generated waste is in the liquid state (Figure 3). Under normal conditions, the average water consumption per day per person is about 182 l (data was obtained experimentally in urban environments), most of which is transformed into waste. This amount of waste can be recycled using advanced biotechnologies.

The liquid fraction of waste can be recycled using chlorella growing plants. For these purposes, the resulting liquid fraction goes into the chlorella cultivation tank. The volume of wastewater entering the plant is sufficient for photosynthesis (according to our estimates, one part of the liquid waste shall relate to 10 parts of chlorella suspension). At the stage of wastewater formation, it is proposed to use only environmentally-friendly and natural means of hygiene and household chemicals to reduce the chemical load in the ECH.

When cultivating chlorella in a nutrient medium from wastewater, minerals should be used as mineral nutrition to enter the collector as a result of household activities

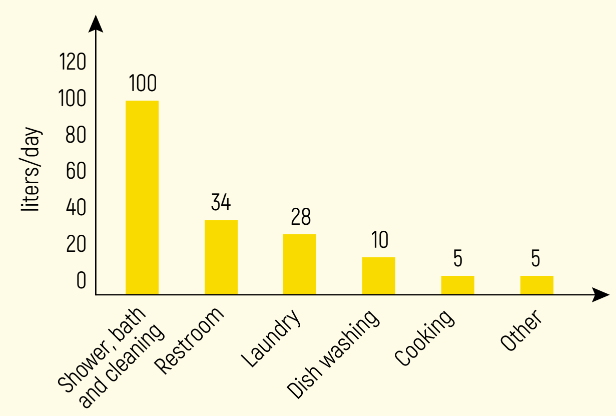
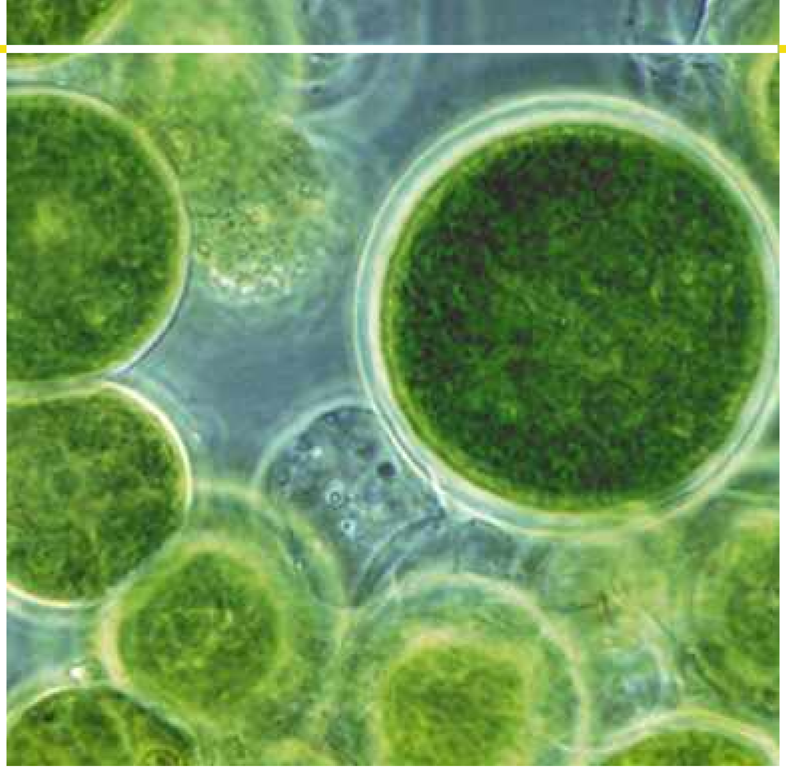


Figure 3 – Average amount of liquid waste generation per person per day

of people living in ECH. In addition, the possibility of introducing wastewater from the economic unit (animal husbandry and crop production) was considered. The quality of the liquid fraction obtained must be constantly checked to understand how much liquid waste will not be toxic to the culture of chlorella. As a benchmark for testing the nutrient medium from wastewater, various media should be selected, proposed by expert scientists [3]. Meanwhile, the installation of chlorella should work with a certain photoperiod in order to conduct wastewater treatment as quickly and efficiently as possible (the possibility of using autotrophic and heterotrophic types of chlorella feeding).

The next step is to filter the suspension through a sand filter and transfer the formed aqueous medium to the marshy part of the fresh lake (natural filtration field), where plants capable of performing biological water purification (cane, typha, duckweed, nutsedge, reed, etc.) should be used. In addition, zoological objects should be included as much as possible into the process. In particular, at one of the stages, bivalve mollusks can be used, which serve as an indicator of the state of the aquatic environment: when the chemical composition of the treated water is unfavorable, the clams of the mollusks are slammed down, and a change in the biological rhythm is noted. In addition to biological indicators, it is required to conduct a rapid test of the composition of the water directly at the outlet of the chlorella cultivator. In case the water



quality at the outlet of the installation does not correspond to the declared parameters, the term of wastewater treatment should be extended.

For the fastest possible waste processing, most of the solid fraction is supposed to be converted into a liquid fraction using a closed-type photobioreactor (Figure 4). It is a closed tube or other capacity of a transparent material capable of transmitting light, which is necessary for the flow of photosynthesis. After the process of mixing with the wastewater, the resulting mixture can already be supplied to chlorella installation.

As installations for chlorella cultivation, it is proposed to use plants (photobioreactors) of closed and open types that are widely practiced in human economic activity (the same photobioreactors will be used at all stages of waste processing).

An open-type cultivator is usually an aquarium that has a significant open surface, which is a great advantage in terms of oxygen release from the installation surface. At the same time, with open cultivation, a greater addition of chlorella mother solution to the system is required (with a frequency of 3–5 days), since gradually an increasing number of different types of invertebrate animals that can enter the system along with the waste will be observed in the installation. In systems of the same type (glass and plastic pipes of different diameters, transparent cubes, etc.), this problem is practically excluded. In order to optimize the work, it is proposed to use a combined system, which will improve the quality of cleaning and increase the volume of oxygen produced in the ECH (80 % of the installation volume should be designed as a closed photobioreactor and about 20 % as an open one).

An open-type photobioreactor for chlorella cultivation is a chlorella suspension tank equipped with a compressor that constantly supplies air into the tank and simultaneously performs non-mechanical mixing of suspension (the general scheme is shown in Figure 5).

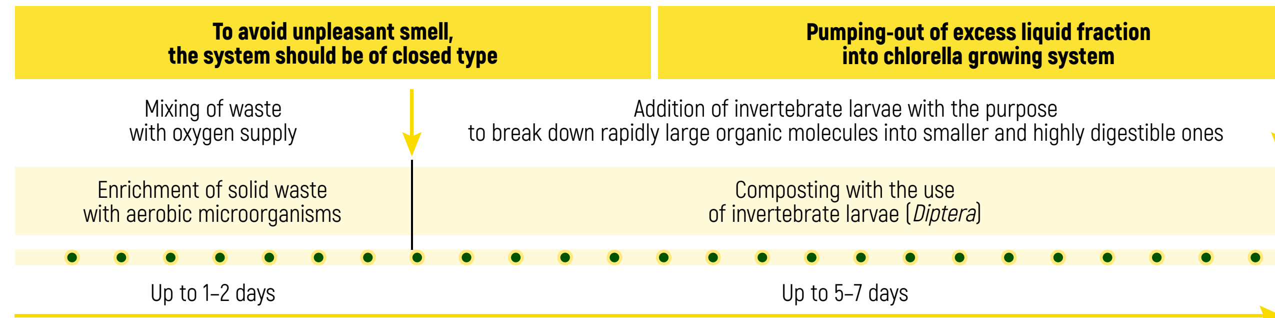
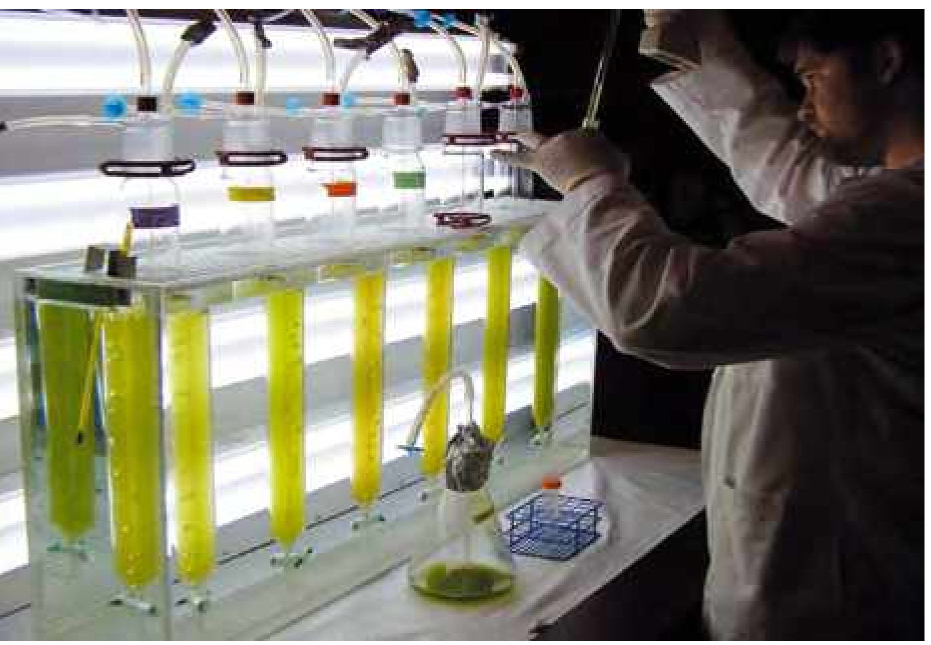
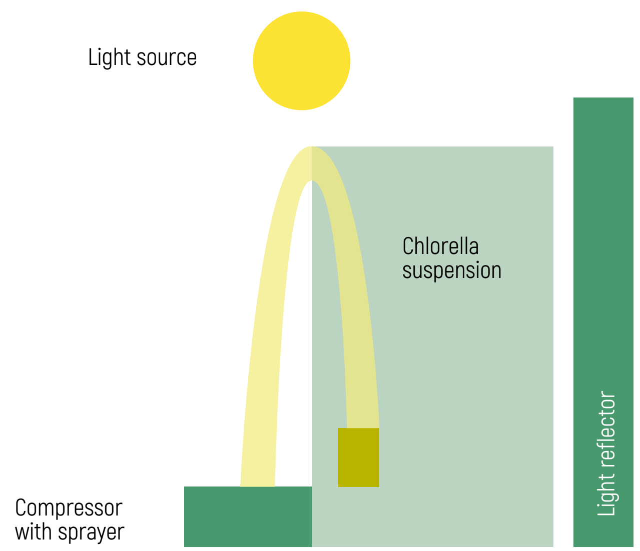


Figure 4 – Element of a biological reactor for processing solid waste fraction





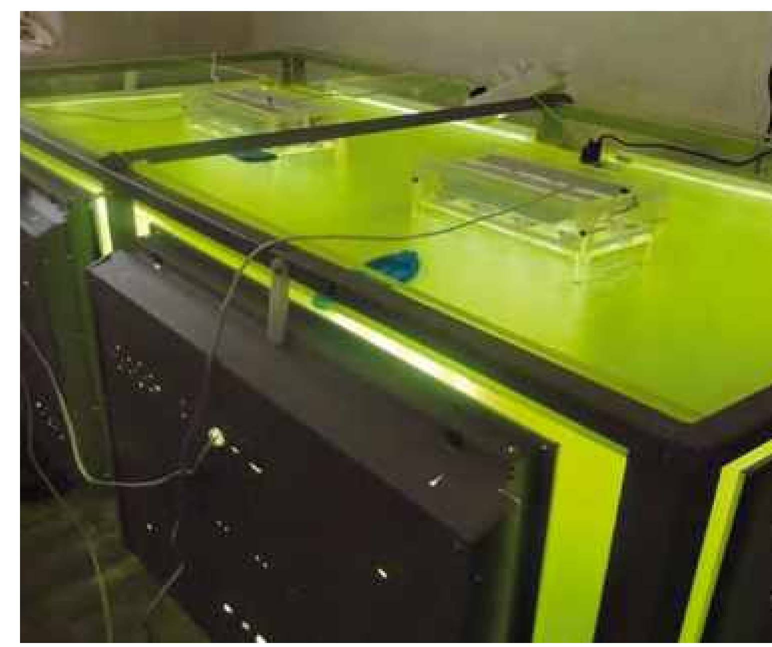


Figure 5 – Scheme and appearance of open-type photobioreactor for chlorella cultivation

At the same time, the use of closed-type photobioreactors (Figure 6) requires the development of a circulation system for chlorella suspension for the purpose of gas exchange. In the case of using a tube-type photobioreactor, it is necessary to provide an oxygen desorber and a system for supplying carbon dioxide or air with its high content. Instead of a desorber, an installation is being developed using a combined system that includes open-type and closed-type photobioreactors.

However, the production of oxygen is also important. According to the results of the experiments with the Siren photobioreactor, it was found that for a person's life in a closed ecosystem, 25 l of suspension are sufficient, which release 429 g of oxygen per day (under normal conditions, the density of oxygen is 1.43 g/l [10]), i.e. about 300 l of O_2 [11]. The small volume of the installation, capable of maintaining the viability of a person, makes it possible to direct the excess of oxygen to a whole range of other biological and physical processes. In addition, it is proposed to use oxygen desorber in order to create a backup storage of this gas, as well as to control the concentration of gas in the air.

Considering the above, the appropriate installation volume is calculated, necessary for living of about a thousand persons in ECH conditions. The capacity of photobioreactor in ECH should be at least 25,000 l of suspension. It will release about 429 kg of oxygen per day with the necessary 906 kg/day of oxygen for a thousand people (with moderate loads, on person needs on average 0.906 kg/day of oxygen [12]). However, taking into account various processes related to oxygen consumption (composting, soil formation), as well as breathing of amphibians and aquatic animals, fish, birds, etc., it is necessary to use plants for growing chlorella with a capacity of about 50,000 l (provided photosynthesizing meadow and forest plants will also produce oxygen additionally in ECH).

It is proposed to install photobioreactors at one of the walls of ECH, closer to the agricultural block (crop raising and cattle breeding). The optimal production of oxygen by chlorella is possible with a maximum duration of daylight hours for it – 20 hours (night – 4 hours).

The resulting suspension of chlorella can be used as a soil fertilizer and feed additive in animal husbandry. It is intended to cultivate chlorella separately on a special nutrient medium in order to obtain an additive to human food. Thus, the use of chlorella allows solving a number of issues related to the viability of the closed ecosystem at EcoCosmoHouse, in particular, the task of gas exchange and wastewater treatment.

Figure 6 – Photobioreactor for closed-type chlorella cultivation

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UDC 621.31

Methods to convert solar radiation energy into electricity for the needs of Industrial Space Necklace "Orbit"

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The article discusses the main types of power plants for energy supply of objects in near-Earth orbit. The principles underlying the conversion of solar radiation into electrical energy are described. The characteristics of the experimental samples of stations implemented in laboratory conditions are given.

Keywords:
solar radiation, space power plant, energy conversion, Industrial Space Necklace "Orbit" (ISN "Orbit").

The main types of energy that will be required for the life support of the Industrial Space Necklace (ISN "Orbit") [1] will be electrical, mechanical, thermal and luminous ones. Solar radiation is the only primary source with the possibility to transform its energy into all usable forms of energy directly in orbit.

Direct or concentrated solar radiation can be converted into thermal energy of heated bodies, and then through direct or machine transformation into electrical energy. The temperatures of the heated bodies depend on the density of the incident radiation and the arrangement of heat transfer processes, including reverse thermal radiation from the surface (Figure 1).

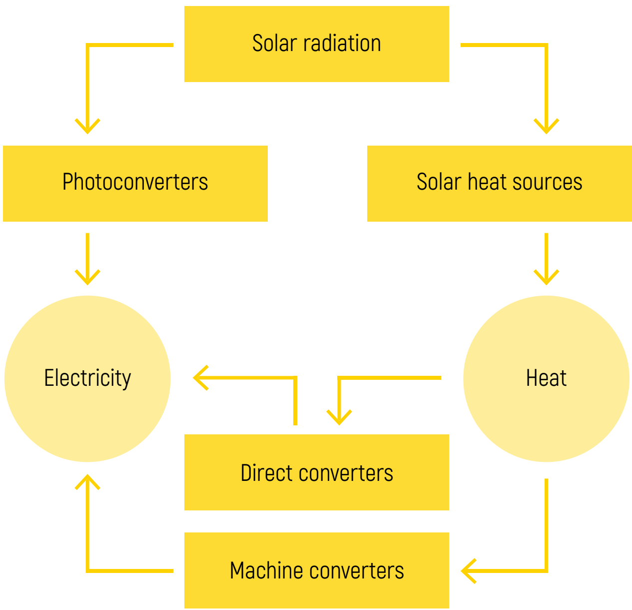
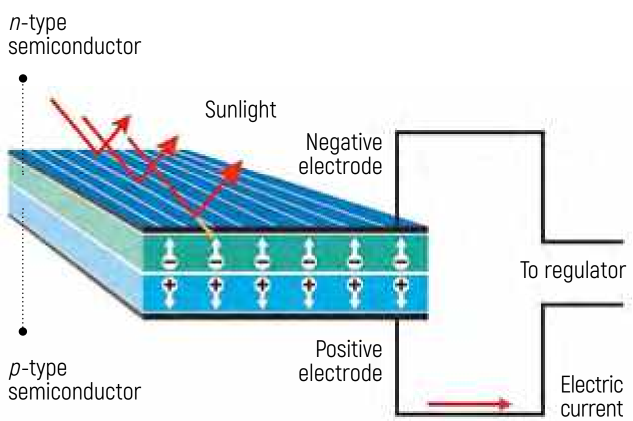


Figure 1 – Diagram of ways to convert solar energy into electricity

Solar energy can be directly converted into electrical energy by means of photoconverters. The maximum flux density of solar radiation outside the Earth's atmosphere is 1,367 W/m^2, and on Earth it is about 1,000 W/m^2 (at the surface perpendicular to the radiation), which is usually much lower due to adverse weather conditions (cloudiness, fog, smog) or economic inappropriateness of building systems for tracking the sun. Accordingly, the effectiveness of any option for generating electricity in outer space will be much higher.

Currently, the most widely used method for generating electricity in space technology is the direct conversion of solar energy into electric power based on the photoelectric effect. A solar cell battery (SB) is several combined semiconductor devices that convert solar energy into direct electric current [2]. The photovoltaic cell consists of two semiconductor wafers made of silicon. To give them conductive properties, boron (n-area) is applied on one of them, and phosphorus (p-area) is applied on the other (Figure 2).

Improving the efficiency of SB is possible in two main ways: the use of new materials and the use of solar concentrators (for example, Fresnel lenses). Concentrators increase the radiation flux density, therefore, reduce the area of solar cells with equivalent output power, thereby reducing the cost of a solar station due to the operation of a smaller number of solar cells.

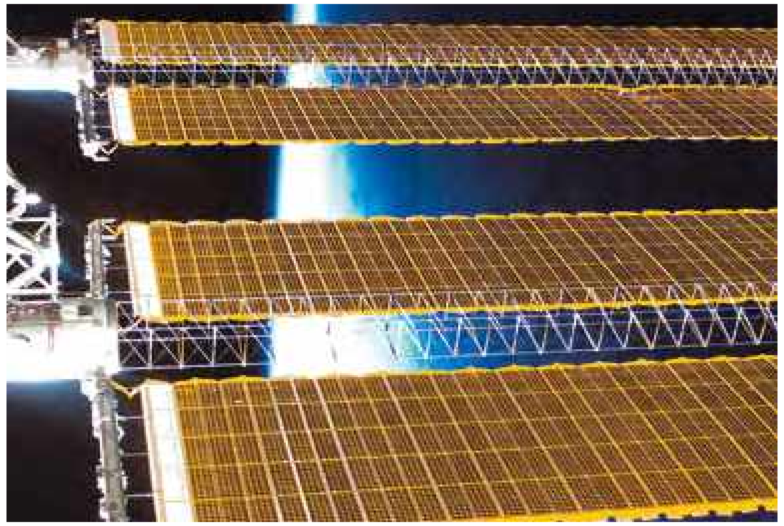


Cross section of a solar cell

Figure 2 – Schematic diagram of solar battery

Objects in near-Earth orbit revolve around the Earth within about 1.5 hours and are periodically in the shade. Therefore, the use of batteries is required. Each of the solar panels (105 m^2) at the International Space Station (ISS) has six nickel-hydrogen batteries. The service life of such batteries is approximately 7 years [3].

Currently, solar cells made of gallium-arsenide heterostructures (GaAs) are promising (in terms of specific power), but they have a higher specific weight and a higher specific cost than silicon-based (Si) panels. At the same time, there is no sufficient volume of their tests (GaAs) in "low" orbits (less than 500 km) in the presence of a noticeable dust "atmosphere" around the station and under conditions of constant thermal cycling (16 cycles per day). The temperature of the solar battery in the shadow of the Earth drops to –45... –60 °C. Moreover, when entering the Earth's shadow, the battery temperature drops in 2–3 min to 70–90 °C. After leaving the shade with frontal lighting, the temperature quickly enough (in 1.5–2 min) rises to 65–75 °C; when illuminated from the back, the SB temperature increases more slowly – in 10–15 min up to 40–45 °C [3]. In this connection, silicon-based photoelectric panels have so far been used on the ISS and transport ships.



Power plants with thermodynamic methods of energy conversion are much more complex in their structure. The design of a solar thermal power plant consists of three main systems: a source of heat, transformation of thermal energy into electricity and heat removal.

Arrangement of heat removal is an important issue in the conditions of outer space, because the methods traditional for terrestrial conditions cannot be used. The only real mechanism for heat removal in space is radiation. Installations designed to remove heat are called refrigerators-emitters.

The defining equation for radiative heat transfer from the body is: $Q_r = \varepsilon A \sigma T^4$,

where ε – emissivity (degree of blackness) of the body surface;

A – heat transfer area;

σ – Stefan - Boltzmann constant;

T – absolute body temperature.

It can be seen from the above equation that the power of thermal radiation of a refrigerator is directly proportional to the area of the radiator, and with increasing radiation temperature, the amount of heat removed increases to the fourth degree. Therefore, to reduce the size and weight of the refrigerator-emitter, it is necessary to raise the temperature of heat removal. On the other hand, as the temperature of heat removal increases, the efficiency factor of the station cycle decreases, which is determined by the expression:

$$\eta = C(T_{max} - T_{min}) / T_{max}.$$

T_{max} temperature should be maximum, however, it is limited by the properties of construction materials. T_{min} temperature is the minimum cycle temperature and should be as low as possible.

Thus, when designing space power installations, it is necessary to solve the problem of choosing the minimum temperature of the cycle. In this respect, the mass of the refrigerator-emitter, which is up to 50–60 % of the mass of the system, should be taken into account. The dimensions of the radiator can be reduced by increasing the maximum temperature of the cycle, which will lead to a drop in the efficiency of the converter. Increasing the maximum temperature of the cycle is possible with the use of rare and expensive materials.

The second group of methods for obtaining electrical energy from solar radiation is an indirect transformation with an intermediate generation of thermal energy. According to the type of converter of thermal energy into electrical one, all solar power plants can be divided into two groups: installations with direct "machineless" conversion of thermal energy into electrical energy and installations with an intermediate change of thermal energy into mechanical energy (using machine converters). Thermoelectric phenomena include a group of physical phenomena caused by the existence of an interconnection between thermal and electrical processes in electrical conductors.

In a closed circuit consisting of different materials, a thermoelectromotive force (TEMF) arises if the contact points (junctions) are maintained at different temperatures (the Seebeck effect). TEMF depends only on the temperatures of hot and cold junctions and the nature of the materials that make up the thermoelement. If there is a temperature difference at the ends of the conductor, a stream of electrons from the hot end to the cold end arises. A negative charge is accumulated at the cold end. The resulting potential difference creates a counter-current of electrons equal to the primary flow caused by the difference in thermal velocities. It is the difference of such potential drops in two conductors forming a thermoelement that causes the occurrence of TEMF.

The first solar thermoelectric generator for space purposes was created in the USA. Thermoelectric elements (TEEL) with a volume of 2.5 mm^3, placed between two plates of metal foil, were used in the design. About 3,000 units were per 1 m^2 (Figure 3). In outer space, the plate facing the Sun heats up to 300 °C, and the cold side has a temperature of about 70 °C. Each element in this structure produces 10 mW with an efficiency of ~ 2 %. 1 m^2 of the thermoelectric panel of the model weighs 10 kg and produces approximately 30–40 W/m^2 of electricity. A solar generator for a spacecraft with a surface of 30 cm^2 with 12 rows of TEEL (12 TEEL in each row) was characterized by the generation of 2 W of electricity in space [4].

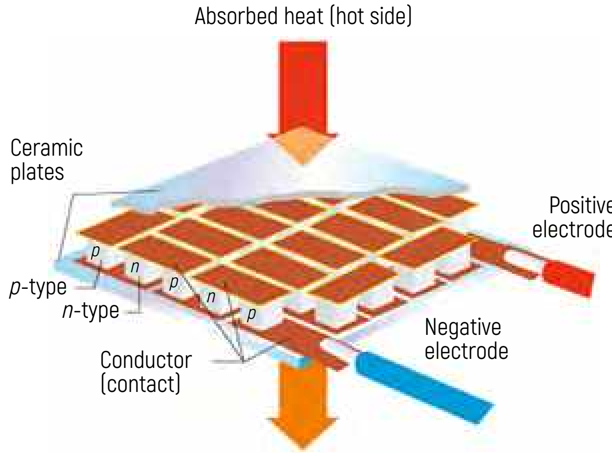


Figure 3 – Thermoelectric converter design

To increase the temperature gradient between hot and cold junctions, it is possible to use solar energy concentrators, which allow increasing the temperature of the hot junction to 1,000 °C. Correspondingly, the efficiency increases, which grows in proportion to the temperature difference between hot and cold junctions and the absolute temperature of the hot junction.

Extensive tests of generator modules were carried out in terrestrial conditions. According to the results, dependences of power, voltage and current on the temperature difference between cold and hot junctions were built (Figure 4) [5].

A thermoelectric module with a concentrator (Figure 5) is a thermopile set at the focus of a spheroidal or cylindrical.

Three main types of machine heat converters can be used in space solar stations – gas piston, gas turbine

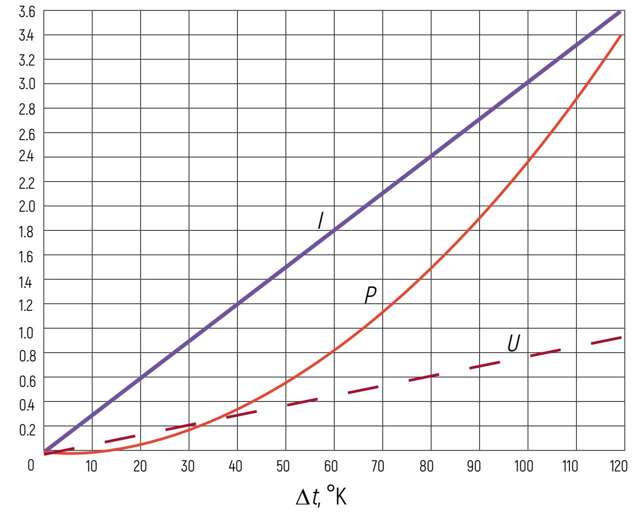


Figure 4 – Dependency graph of current *I* (A), voltage *U* (V) and power *P* (W) on the temperature difference between the hot and cold sides of the generator module

and steam turbine, implementing Stirling, Brighton and Rankine cycles.

In solar thermal power installations with machine converters, thermal energy is supplied to the working medium of the converter, which is in a liquid or gaseous state, and is converted into mechanical energy in a steam or gas turbine converter or in a piston machine. Then mechanical energy is converted into electrical energy using an electric generator.

Stirling engines are machines with reciprocating motion (many other schemes of Stirling engines with rotational motion are possible).

The American company General Motors also created a 3 kW space power plant. Helium was used as the working medium for the Stirling engine at an average pressure of 10.3 MPa, and heating was carried out by means of solar radiation, which was concentrated using a large Fresnel lens. A distinctive feature of this engine is as follows: this is the first of the Stirling engines, using an intermediate liquid metal coolant (NaK) at a temperature of 677 °C to heat the working fluid. The calculated efficiency of the engine is 30.5 %. During the first tests, a power of 2,565 W was achieved with an efficiency of 23 % [6].

In the cycles of gas turbines for space purposes, inert gases and their mixtures are used as working fluids. Their positive side is the absence of phase transformations and the almost complete absence of erosive and corrosive effects of the working fluid on the design of the converter.

The Brighton cycle has a relatively low efficiency, large costs of turbine power to drive the compressor and significant pressure losses in the working fluid in the elements of the heat exchanging equipment of the converter. As a result, the characteristic values of the utilization coefficient for gas turbine converters do not exceed 0.25, and to obtain high efficiency of the converter, it is necessary to increase the temperature difference in the cycle, mainly due to the increase in the gas temperature in front of the turbine, i.e. in the radiation receiver.

The isothermal nature of the processes of supply and removal of heat in steam turbine converters significantly raises the thermal efficiency. In addition, unlike gas turbines, there are lower costs to drive the pump, which in the complex allows to obtain rather high values of the utilization factor (~ 0.5) and, consequently, the effective efficiency (20–25 %), which increases with increasing the installation capacity. These factors determine the main, in terms of the requirements for thermal converters of solar energy, advantages of steam-turbine converters over converters operating according to the cycles of Brighton and Stirling.

The efficiency of steam turbine converters largely depends on the properties of the working fluid, which can be water, liquid metals and organic compounds. The developers of thermal solar space station projects have concluded that the most suitable working bodies for steam turbine converters are liquid metals. Potassium and cesium are among the most optimal, but potassium is preferred, because of its greater availability in the quantities required for the plant.

The effective efficiency of piston machines is usually higher. This is especially true for low power, which is associated with large leaks in the blades of low power turbines. At low power (up to 1 MW) Stirling engines are preferable to engines operating under the Rankine cycle, because of the simple design, greater efficiency and unit power. Moreover, for Stirling engines, the choice of pressure

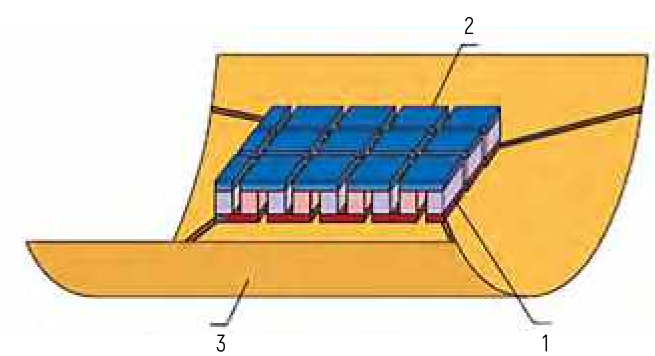


Figure 5 – Thermoelectric module on a cylindrical concentrator:
1 – hot junctions, 2 – cold junctions, 3 – concentrator

and temperature can be made independently, which is impossible for systems with a vapor-like working fluid. In space power installations, efficiency is the determining factor. With high efficiency, there is less space and weight of the refrigerator-emitter, since less heat is required from the station.

For space conditions, it is possible to have a modular design of the station, when the required power is composed from a certain number of standard units (Figure 7) [8].

Table shows the design parameters of space thermal power installations with machine converters of thermal energy into electrical one [7].

An alternative option of the working medium in a thermal power plant may be a magnetohydrodynamic generator (MHD generator) – a device in which the energy of the working medium moving in a magnetic field is transformed directly into electrical energy. The principle of operation is based on the phenomenon of electromagnetic induction, i.e., a current arises in a conductor crossing the magnetic field lines. The conductor in the MHD generator is the working medium itself, in which the flow of charge carriers occurs when moving across the magnetic field. Electrolytes, liquid metals and ionized gases are used as working fluids. Solar thermal energy is used to accelerate and ionize the working fluid.

To create the electrical conductivity of a gas, it must be heated to a thermal ionization temperature (about 10,000 °K). For operation at lower temperatures, the gas is enriched in alkali metal vapors, which makes it possible to lower the temperature of the mixture to 2,200–2,700 °K. The speed of the plasma in the generator channel after acceleration during the passage of the nozzle is about 2,000 m/s.

Compared to steam and gas turbine cycles, the advantage of a system with an MHD generator is the absence of rotating parts, which increases the reliability of the station. In addition, MHD generators can be used in power plants

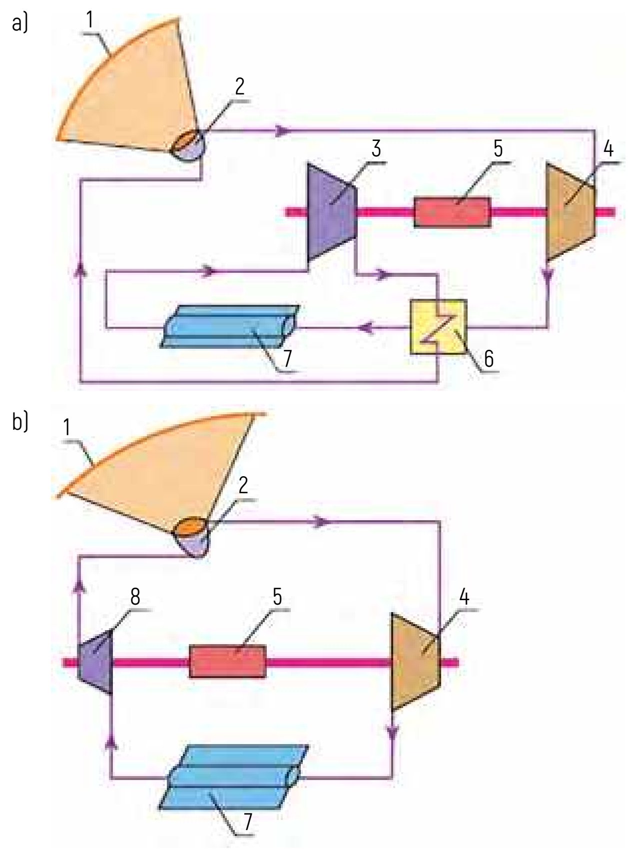


Figure 6 – Schematic diagrams of the solar gas-turbine and steam-turbine power plants:
1 – concentrator; 2 – solar boiler; 3 – compressor;
4 – turbine; 5 – electric generator; 6 – regenerator;
7 – refrigerator-emitter; 8 – pump

with combined cycles. In this case the total maximum electrical efficiency of the plant will be 55–60 %.

Thus, there are many ways to generate electricity due to solar radiation in space. All of them are rather deeply

Table – Design parameters of space thermal power installations with machine converters of thermal energy

Convertor type	Working medium	Output power, kW	Efficiency factor, %	Weight, kg	Concentrator diameter, m
Gas reciprocating with Stirling engine	Helium	5	20	258	5.7
Gas turbine	Helium-xenon	2–10	15–22.7	–	9.2
Steam turbine	Mercury	3	12	236	9.6
Steam turbine	Rubidium	15	24	454	13.5

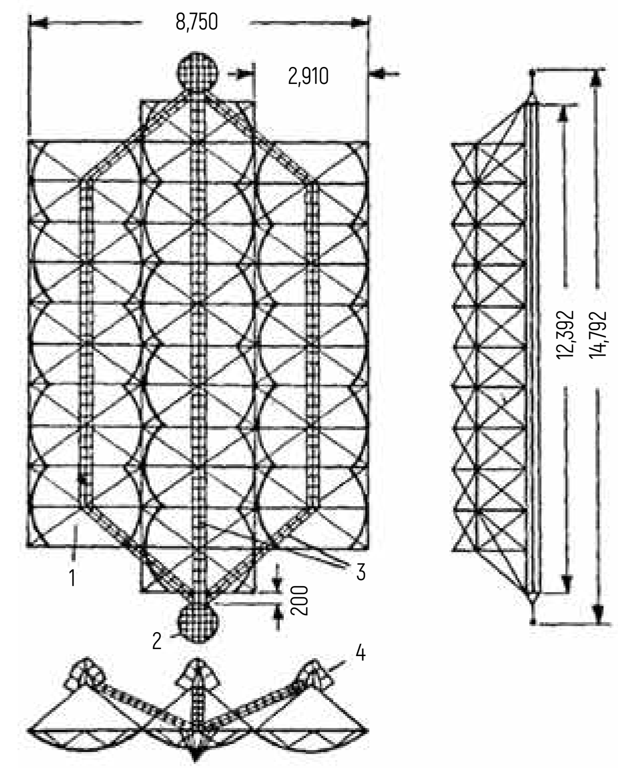


Figure 7 – Diagram of a 16-modular SSPL
with a gas turbine converter (dimensions are indicated in meters):
1 – concentrator; 2 – antenna; 3 – power switchboards;
4 – refrigerator-emitter

worked out only theoretically and on mock-ups in the laboratory. The exception is the photoelectric method of producing electricity, which is currently used to power the satellites and the ISS.

Of the options described, the most optimal in terms of efficiency are thermal power plants with machine converters. The efficiency of such stations reaches 36 %, and during the passage of combined cycles, including with an integrated MHD generator, 60 % and above (while the efficiency of photovoltaic power plants is at the level of 14–20 %, and that of thermoelectric power plants is about 2 %). When comparing the specific mass values of power plants, photovoltaic power plants are more attractive, for which this indicator is 1.4–3 kg/kW (for stations with machine converters – 30–78 kg/kW, for thermoelectric stations – hundreds of kg/kW). The service life of photovoltaic panels is about 30 years, and thermal power plants – at least 40 years.

Since the arrival of solar radiation in orbit is cyclical (one cycle lasts 1.5 hours), it is obvious that the graphs of electricity production and consumption will not be the same.

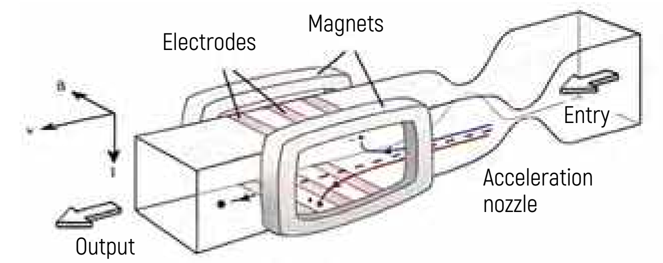


Figure 7 – Magnetohydrodynamic generator

For power supply of the ISN "Orbit" power plants of considerable capacity will be required – about 10 MW, and, therefore, powerful energy accumulators will be needed, too. At present, high-capacity electric batteries are inefficient and very expensive due to the need to use rare materials. Heat accumulators are simpler and less-costly in design and have a much longer service life. They have been studied, tested and operated at all terrestrial steam-turbine solar power plants (they provide round-the-clock operation of the station, that is, they produce electricity, even at night). Accordingly, high-capacity heat accumulators are economically preferable than electric ones. Consequently, it is easier to ensure constant electrical power output from a thermal conversion power plant.

At the same time, thermal power plants are more complex in their structure, there is an additional thermal economy (due to the presence of an intermediate energy conversion) and auxiliary systems. This means a higher risk of equipment failure due to the presence of a larger number of component parts. However, for ISN "Orbit" the need for the constant presence of staff is not a limiting factor.

A promising direction is also the technology of decomposition of water by solar radiation into hydrogen and oxygen by any known method, followed by direct or indirect "burning" of hydrogen and oxygen in any of the known types of power plants, for example, gas piston or using fuel cells, in which electrical energy is converted into electricity bypassing the burning. In this case, a part of hydrogen and oxygen can be consumed in orbit, and a part can be delivered to the Earth's surface for use in power engineering and transportation.

These technologies are ecologically safe both in orbit (they can even be used inside space settlements – EcoCosmoHouses) and on Earth, since distilled water is the product of the combustion of fuel in them. In addition, the cyclical nature of solar lighting in orbit will not affect the operation of such power plants and will not require energy storage devices – thermal or electric, since fuel and oxidizer will accumulate.

At the same time, terrestrial ecology will not be disturbed – the water taken from the planet will return to it after passing through the energy cycle. With the delivery of water to the orbit in the amount of millions of tons, and back – of hydrogen and oxygen, there will also be no problems when using the General Planetary Vehicle (GPV) as a geocosmic transport system due to the fact that its ballast system can be filled only with water [1].

Taking into account all the listed features and specifics, thermal power plants of combined cycles are more reasonable for high-capacity power stations that will be required for power supply of industrial and residential centers as part of ISN "Orbit".

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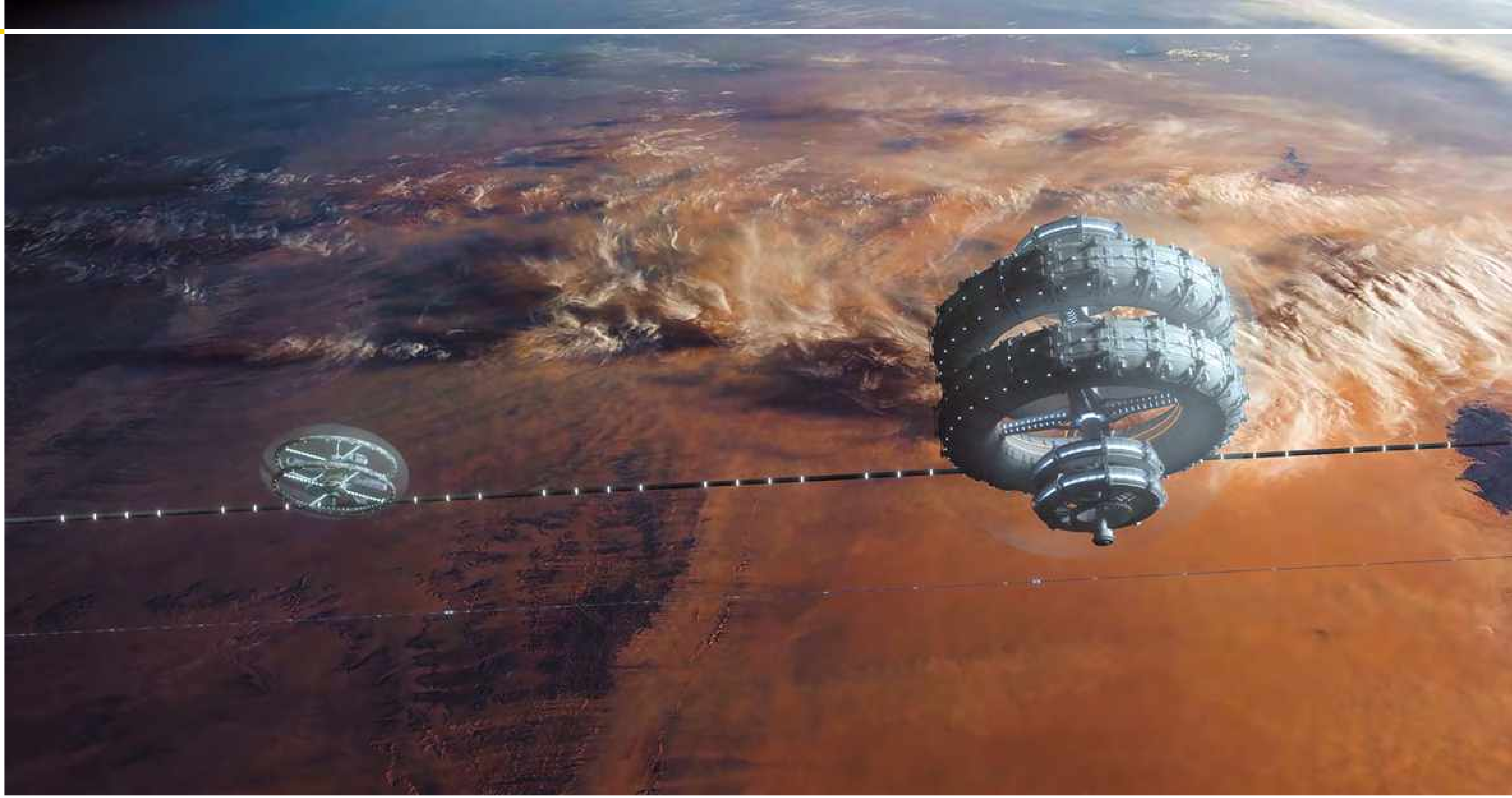

UDC 504.4.062.2

Hydrosphere of EcoCosmoHouse on the planet Earth and its components

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This article discusses the main points regarding the operation of artificial water bodies and hydrological operating regimes occurring under the conditions of artificial hydrosphere. Some problems of human influence on the state of EcoCosmoHouse hydrosphere on the planet Earth (ECH-Earth) are analyzed.

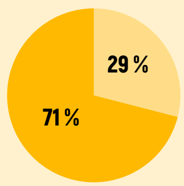
Keywords:
hydrosphere, hydroecology, water circulation, water exchange, water purification, EcoCosmoHouse on the planet Earth (ECH-Earth).

The total volume of the Earth's hydrosphere is 1.39 billion km^3 [1]. This circumstance determines the dominant habitat of our planet. At present the state of water bodies indicates a significant pollution and gradual degradation of the hydrosphere due to the anthropogenic factor. In most cases, due to the technogenic impact of mankind, a complete self-purification of natural waters is no longer possible [2].

The nature of the location of water bodies on the planet, as well as their interrelation, makes it possible to transfer mineral and organic substances within the biosphere, which, in turn, emphasizes the high importance of water bodies for maintaining balance in nature. It is also important that water occupies a significant part in the structure of living organisms, providing not only a binding function uniting all tissues and organs, but also carrying out transfer of useful substances inside the body. Thus, the aquatic environment determines life on our planet [2].

While creating a model of an artificial ecosystem, one should consider in detail the presence of water bodies and their control in a confined space. Thus, while recreating artificially the hydrosphere in EcoCosmoHouse project on the planet Earth (ECH-Earth) [3], suitable for permanent residence of a group of people in an isolated space, it is necessary to simulate an optimal circulation of water flows, taking into account the main hydrological processes occurring on Earth. When implementing this project, it is necessary to analyze a number of aspects: time frame and water circulation in an artificial hydrosphere, types of water bodies, basic and additional purification methods to maintain continuously the required water quality, anthropogenic impact on the state of water bodies, accumulation and methods of rational use of limited water resources.

THE RATIO OF LAND AND WATER



Land area – **149 mln km^2**
Water area – **361 mln km^2**

FRESH WATER CAPACITY

Surface and atmospheric water	**1.2 %**
Groundwater	**30.1 %**
Glaciers	**68.7 %**

SURFACE AND ATMOSPHERIC WATER

69 %	Freshwater lakes and rivers
12.2 %	Soil moisture
9.5 %	Atmospheric water
9.3 %	Other sources

Creation of a confined ecosystem (similar to the terrestrial one in terms of area, where three quarters are allocated for water bodies and a quarter – for land) will not allow us to accommodate a sufficient number of people inside rationally and fully provide them with living areas where it is possible to build housing, plant trees and shrubs (which will provide an additional opportunity to convert carbon dioxide into oxygen), cultivate fields and pastures, engage in animal breeding and conduct intensive agriculture, satisfying at the same time the main need for food of plant and animal origin.

Another difficulty in the implementation of the project can be re-creation of the natural water circulation, which occurs on Earth once every eight days [4]. Under limited conditions, without the use of mechanical water lift, it will not be possible to utilize fully water vapor as the main source of rainfall. Thus, on excluding the processes of vaporization and moisture condensation, fresh water should be pumped into irrigation pipelines equipped with sprinkler systems and used as the only possible source for the creation of artificial rainfall and subsequent redistribution of water on the land surface.

Taking into account the complexity of recreating a self-sustainable artificial ecosystem, it is necessary to treat every detail of its components responsibly. So, the hydrosphere should include fresh and brackish ponds, thermal spring, streams, wetlands and groundwater. Accordingly, the freshwater pond will play the role of an accumulator of the main volume of surface water, combining a number of functions in itself, such as: cultivation of plants and valuable organisms, fish farming, irrigation, recreation (bathing, fishing, active and passive forms of recreation in the coastal zone).

A brackish water body can act as an isolated seafood farm for growing and cultivating valuable species of organisms and algae, for which this environment is natural.

Waters of a thermal spring (30–35 °C temperature) can be used as a natural heat carrier in order to maintain microclimate, as well as for therapeutic purposes. For example, they favor the existence of a number of orderly organisms that clean the human skin.

The presence of a stream is dictated by the need to arrange surface runoff and ensure constant circulation between the freshwater pond and wetland areas (surface filter). Wetlands are the most efficient ecosystem on the planet, counteracting the accumulation of CO_2 in the atmosphere. During a year, one hectare of such land absorbs 550–1,800 kg of carbon dioxide from the atmosphere, which is 7–15 times more efficient than a forest of the same area and releases 7–15 times more oxygen: 260–700 kg [5]. Swamp moss (sphagnum) – an excellent antiseptic – does not allow developing for even those bacteria that can exist without oxygen. In addition, peat in the swamp binds harmful substances into insoluble compounds. All this allows using water from surface sources for drinking water supply, breeding valuable species of fish, regulating microclimate inside the ecosystem and creating a natural self-cleaning filter.

The constant movement of surface water as a result of infiltration through the strata of various soils (sand filter) can have a positive effect on the state

of groundwater. Smoothly flowing from one layer of soil to another, ground water passes a difficult path over time until it reaches a fresh water body to continue its circulation.

When creating a sand filter as an intermediate filtering layer in order to separate layers of different soils and coarse granular materials, geotextiles of various densities can be used. This intermediate layer is needed to prevent wash-out of vegetable soil enriched with humus into the lower layers consisting of different chemical and granulometric composition of mineral soils. This, in turn, allows the nutrient solution to be applied to the upper layers of the plant soil for intensive organic farming and to use the lower layers containing different fractions of mineral soil as a sand filter, while avoiding mix-up of adjacent layers. Thus, a purification process can occur, accompanied by the enrichment of water with minerals and micro-elements. At the same time, the total volume of water inside the hydrosphere remains unchanged.

Man has an anthropogenic effect on the hydrosphere in one way or another: by dumping household and sewage into water bodies bringing organic fertilizers, herbicides and pesticides in agriculture. Water resulting from human and animal life should be directed to an isolated underground drain so that it does not affect other surface and groundwater bodies without proper purification. It is permissible to mix wastewater with food residues and pre-fine-cut waste of plant origin for subsequent use in the production of humus (Dano biostabilizer method). Excess moisture can be filtered and accumulated in a settling tank, where the process of disinfection, purification (activated silt) and enrichment with organic substances (chlorella) takes place up to the stage of a nutrient solution (organic fertilizer).

Subsequently, the nutrient solution may be used for watering and irrigation of crops, trees and shrubs. Excess moisture generated during irrigation is filtered into the ground, passing through a natural sand filter, which is a layer of vegetable soil enriched with humus, underlain by layers composed of sands of various fractions, minerals and stones. To accelerate the flow of filtered water into a freshwater body, a deep systematic drainage should be arranged (perforated polyethylene pipes of various diameters, coarse stone layers) under the entire area occupied for cultivation of agricultural crops and other plants.

When implementing a new "Ark", it should be borne in mind that to build it, the existing resources of our planet will be used, which are already polluted now, being affected by anthropogenic impact in one way or another. Humanity today should protect the hydrosphere of the Earth and realize that fresh water is the most valuable and limited resource that we possess. The total water reserves on land including waters in lakes, rivers, glaciers and the underground basin are estimated at 48 million km^3, which is about 3.5 % of the total volume of all water on the planet. The supply of fresh water is estimated at 35 million km^3, which is about 2.5 % of the total mass of land waters [4]. This does not mean that there is little fresh water on Earth: it's just that man has not yet learned how to use it rationally. This amount of fresh water, provided it is evenly distributed, is two or even three times more than is necessary for today's population of the Blue Planet.

Summarizing, the implementation of the ECH-Earth prototype will allow us to analyze in practice and correct (if necessary) the adopted project solutions, check the operation of both all systems as a whole and individual equipment, as well as conduct tests in emergency situations, develop and configure the maximum number of systems to operate in automatic or semi-automatic mode, exclude all possible emergencies and develop effective measures for their elimination in the process of operation.

After the launch of the ECH-Earth project, all interested participants and project testers will gain invaluable experience of harmonious human existence on a par with other inhabitants of the biosphere in a favorable and environmentally friendly habitat. And for the future residents of ECH, delivered into Earth's orbit or located in open space, the issue of maintaining a healthy hydrosphere and ecosystem is particularly relevant, since in this situation human health will directly depend on the state of all systems within a confined artificial biosphere.

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UDC 681.5.017

Equatorial Linear City as an alternative to the concept of smart cities

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The article discusses the project of creating the Equatorial Linear City (ELC) as an integral component of the TransNet ground network of string roads based on SkyWay and HyperU transport and infrastructure complexes, as well as the ground infrastructure of a geocosmic transport complex – the General Planetary Vehicle (GPV). Thanks to the use of modern informational and other technologies, the cities of ELC can act as an alternative to traditional projects of smart cities, with the possibility of upscaling the "smart concept" to the level of individual countries, and in the future – global regions. In support of this thesis, there are described the key advantages of ELC in comparison with traditional and smart cities including: integration with the transport system of the new generation, inclusion into the program of SpaceWay industrial exploration of near space.

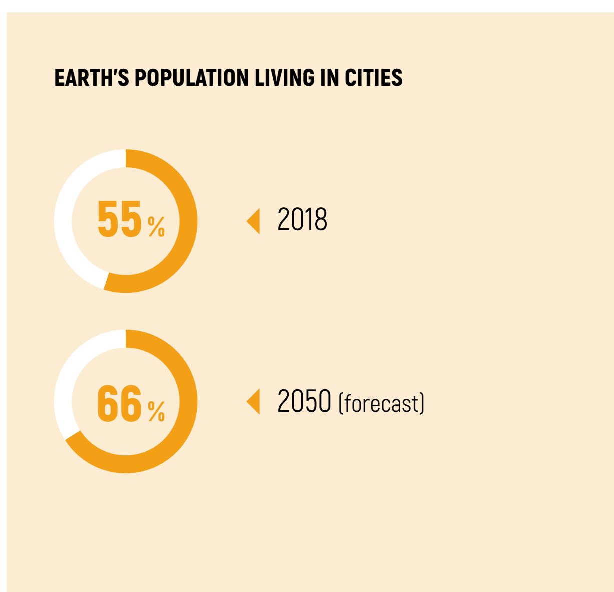
Keywords:
Equatorial Linear City (ELC), smart city, SkyWay, HyperU, TransNet, General Planetary Vehicle (GPV), Internet of things, cloud technologies, urbanization, hub city, sustainable development, SpaceWay.

One of the main reasons for the formation of cities is the need to ensure effective access to the infrastructure needed for man: to places of residence and work, medical and educational institutions, retail and entertainment and much more. Effective access to infrastructure implies the existence of operating transport arteries. It is transport that determines the structure of the urban environment acting as sort of a frame. The process of expanding urban space is associated with the development of mobility technologies, therefore emergence of a new mode of transport always entails a change in the concept of the city. Thus, creation of a complex of fundamentally new transport systems SkyWay and HyperU is a necessary condition to implement the geocosmic project of the General Planetary Vehicle (GPV) developed by engineer A. Unitsky [1]. This project, in turn, also involves the creation of a global ground-based communication infrastructure – the Equatorial Linear City (ELC), which can become a fundamentally new type to arrange the urban space of the future.

Rapid urbanization has already led to the fact that as of 2018, 55 % of the Earth's population lived in cities; by the middle of the century this figure may reach 66 % [2]. At the same time, the pace of human life in megacities is steadily accelerating, urban infrastructure is experiencing increasing quantitative and qualitative loads. All this leads to the obsolescence of the concept of a classic city originated millennia ago and greatly changed under the influence of the industrial revolution. This concept ceases to meet the new challenges of time.

Cities act as global financial, industrial, political, cultural and communication centers. They have a huge industrial, scientific, technical and creative potential [3]. However, over time, the urban environment has become a structure characterized by an extreme degree of instability. This is due to a number of problems: overcrowding, overproduction, high concentration of waste, emissions of harmful substances, poisoning of fertile land, traffic congestion, outdated infrastructure. A number of these and other factors caused deterioration of ecology of traditional cities. As a result, the life of a city dweller is not only becoming less and less comfortable, but also threatened. At the same time, the existing vector of development of modern technologies does not allow to correct the situation.

So, the rapid growth of cities is associated primarily with the formation of transport communications. Historically, the dynamics of urbanization has passed from the first compact pedestrian settlements (size up to 5 km) to the emergence of large cities – at first with horse-drawn transport (city size up to 20 km), and then with road transport (city size up to 50 km or more). Thanks to transport, man received quick, within half an hour, access to the sphere of production and services, consumer goods, education systems, health care, culture, places of mass recreation and entertainment. The need for physical contact between large groups of people is realized through transport interaction: first with the help of the muscular force of domesticated animals, then with the help of mechanized transport, which has gradually become personal, commercial and social. Centuries later, cities and transport systems united not thousands, but millions of residents. It is transport accessibility that has shaped the cities and determined their size. However, with the expansion of cities, travel time began to reach 1 hour or more due to a decrease in the average speed of traffic. As a result, such cities have become unattractive for living, despite other benefits and advantages.



Modern megacities and urban agglomerations create large-scale systems with dozens of millions of residents. At the same time, a kind of the city's frame is the transport and logistics infrastructure (including city roads and streets), which, like arteries, provides for circulation of goods, services, resources, finances and people. And it is just it that determines the spatial appearance of modern cities. However, an excessive concentration of people and the need to ensure their access to basic goods have led to the fact that existing transport communications can no longer cope with their main mission. This is expressed in constant traffic jams and traffic collapses, as well as in progressing environmental pollution of soil, air and water. Thus, it can be stated that modern transport and the concept of a traditional city with it has come to a dead end for a variety of reasons.

The logic of the formation of urban space can be described as follows. It was preceded by a compact settlement, in which relatively few people lived walking on foot, and which were often built into the existing natural environment without introducing intense disharmony. The emergence of autonomous cities with transport infrastructure led to a local violation of the natural environment; a destructive anthropogenic impact spread to the settlements around cities. Due to the merging of cities in agglomerations, local forms of interaction between urban and natural environments give way to regional forms. As a result, vast territories between cities are also involved in the process of urbanization, causing deep negative changes in the natural environment. The modern stage of urbanization is already an agglomeration of agglomerations with increased anthropogenic pressure on the environment due to the "overlap effect" [4].

Thus, the dynamics of the urbanization process from a settlement to an agglomeration of urban agglomerations leads to an increase in the scale of anthropogenic pressure on the natural environment. Several approaches have emerged to remedy the current situation against this background. One of them acquires the features of alarmist type and is characterized by an extremely negative attitude to urbanization and technological progress, which is expressed in appeals for curtailment of production, cessation of urban growth and stabilization of the population size. However, this approach is criticized because of its focus on slowing down the development of humanity, being, in fact, a dead end and reactionary.

Another approach is associated with the adoption of the idea to solve global problems of mankind through the development of technology. A particular example is the increasingly popular idea of creating smart cities. This concept is based on a number of technological advances, a special place among which occupy: wireless data transfer, miniaturization of devices, cloud technologies, fog computing, formation of the Internet of things (IoT). How does a city acquire smart status? If we select a simplified scheme, then this process is as follows. A large number of different sensors collect a variety of information about the activities of people and businesses through the Internet of things. The information obtained (big data) is processed by algorithms and is used to improve the efficiency of city management, allowing to learn about the needs of residents and industries, problematic areas of urban infrastructure, the ratio of demand and supply of urban resources and services.

The use of the IoT technology and the need for high computing power to process the collected big data predetermine the participation of technological giants in projects to create smart cities. One of the first such companies was IBM, which announced in 2006 the launch of the Smarter Cities program [5]. Another example is related to the activities of Hewlett-Packard, which started in 2009 the Central Nervous System for the Earth (CeNSE) project [6], involving deployment of millions of nano-sensors that collect various data (temperature, humidity, pollution level, etc.) from the environment including that from the urban space.

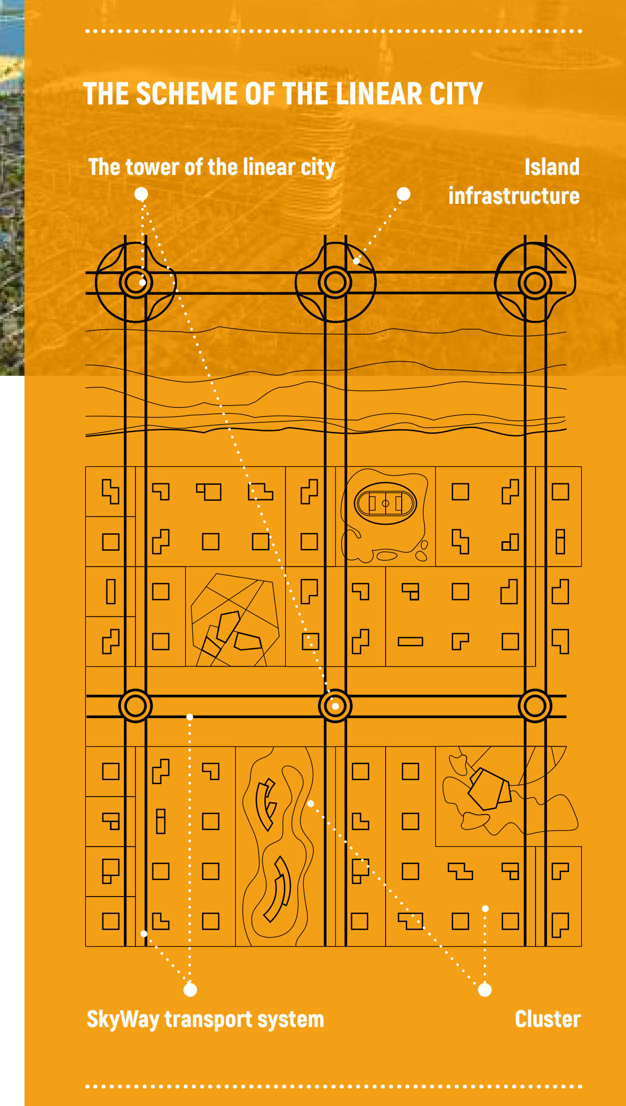
It should be noted that the easiest way to implement a "smart concept" in cities with more modern infrastructure. It is even easier to do this as part of building new areas or settlements. For example, in 2006, the authorities of the Emirate of Abu Dhabi embarked on the implementation of the "Masdar Project", an eco-city of the future capable of providing itself with energy from renewable sources that has a sustainable environmental environment while minimizing harmful emissions. Environmental friendliness is achieved through a ban on personal transport and the use of urban automated transport system, as well as through processing garbage and recycling of waste. Of course, all city services and systems are integrated into a common smart network. It was originally planned to implement the "Masdar Project" by 2014, but financial and other problems prevented this; construction of the city continues.

It should be noted that there are many obstacles to the emergence of smart cities. First of all, they are connected with the strategy itself, which does not imply a change in the city development concept, but concentrates only on new ways of solving old urban problems. Such cities, equipped with a variety of sensors, can be called "perceiving" rather than "smart". Hardly their susceptibility and awareness can, for example, change the outdated urban layout and inefficient transport and logistics infrastructure. Also, such properties are hardly capable of fundamentally improving the outdated road transport that creates smog in cities, as well as kills and cripples hundreds of thousands of people on city streets every year.

An alternative strategy is the project to create the Equatorial Linear City of the cluster type as part of the geospace transport and infrastructure program SpaceWay [1]. ELC are pedestrian clusters of about 1 km area located along the equator and connected with each other by networks of transport, power, and other engineering and communication infrastructures. Residential, industrial, commercial, sporting, agricultural and other ELC clusters are united by a launching bridge of the General Planetary Vehicle (GPV). The GPV overpass, in turn, is combined with SkyWay transport complexes (speed – up to 600 km/h) and HyperU (speed in a forevacuum tunnel – over 1,000 km/h).

Each cluster in this system is a specialized settlement, which is also a communication hub – a transport, energy, information, and other ones – of the global ground network TransNet, and together with GPV and the Industrial Space Necklace "Orbit" – of the U-Net geospace network, which unites the entire planet and near-Earth space into a unified transport and infrastructure complex.

ELC is an eco-friendly city, with developed public transport, green power generation and a highly developed economy. The widespread use of information technology makes this city efficient and its development is predictable, sustainable. The ELC concept involves the rejection of personal transport, which requires serious investments, not only at the time of purchase, but also as constant maintenance costs. For example, in megacities there is a problem



of transport storage, which is not used much of the time and occupies the urban area. That is why in modern smart cities, taxi services adapted for modern technologies (Uber, Yandex.Taxi, Lyft) and car sharing are becoming increasingly popular. However, these new types of services do not allow to solve the transport problems of a city.

The way out is to create a fundamentally new transport network located not on the land surface, but on the second level – automated, efficient, safe and environmentally friendly one. Such a network of roads will leave the surface of the earth, as it always was, for life – for plants, animals and people. These requirements were taken into account already at the design stage of SkyWay and HyperU transport systems, which are the "framework" of ELC creation.

As for the spatial arrangement of ELC, it is a linear city located along the transport and communication infrastructure. This ensures pedestrian access to industrial, public and other objects acting as points of attraction. Residential buildings in ELC are mainly represented by cottage development, which allows reducing the population density and raising the level and quality of human life.

Another important aspect of ELC is its progressive economy. Each infrastructure cluster in the ELC system is a transport hub, which gives a significant impetus to the development of the local economy allowing such settlements to become financial, industrial, trading and logistics centers. Just as throughout the whole history of mankind, the cities located at the crossroads of trade routes became centers of powerful states, so the hubs of ELC may occupy in the future an important position in the global economy and politics. Moreover, it is also worth paying attention to the fact that ELC cities are based on the principles of a "green" economy, which implies supply of power from environmentally friendly sources for the needs of the city and urban industries.

Hub cities of the ELC system can be built not only in the logic of the linear scheme. It is possible to combine intersecting linear cities into a single "chess" metropolis, which will ensure their effective transport accessibility, as well as involve large areas with low population density in the economy. Therefore, the concept of ELC can be adapted not only to individual countries, but also extended to global regions of the world.

Thus, today one of the trends in solving the problems of a modern metropolis is the creation of smart cities. However, such projects are implemented sporadically, outside the systematic approach. This is conditioned largely due to the difficulty of adapting existing urban infrastructures to comprehensive digitalization. At the same time, the growth of the Earth's population and the increasing scale of urbanization lead to the emergence of new settlements,

settlements, which should use advanced infrastructure and transport solutions already at the design stage, as well as be focused on the implementation of the concept of sustainable co-evolution of humanity and the biosphere.

The project to create the Equatorial Linear City is seen as the most promising way of arranging the planetary urban space of the future - its backbone, as both GPV and the orbital industry, tied to the needs of all mankind, can function based on the laws of physics only in the equatorial plane.

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Resolution of the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects"

On the 21st of June 2019, the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects" was held in Maryina Gorka town. The event was held to summarize the results of scientific, research and practical work carried out in research institutes, design bureaus and performed by individuals in the following areas:

- solving actual global problems using space tools;
- prospects for industrial space exploration under the SpaceWay program;
- creation principles, theory and calculation of the design of a non-rocket geocosmic transport – Unitsky's GPV;
- features of the organization of large-scale cargo and passenger traffic along the Earth – Orbit – Earth route;
- search for and development of solutions to actual tasks of biological, ecological and engineering nature when creating the EcoCosmoHouse as a closed local biosphere for preserving the biodiversity of planet Earth, developing areas with adverse conditions for human life, as well as creating a model of future human settlement in outer space;
- establishment of an international organization, the EcoSpace Club, to consolidate the efforts of the world community to ensure the sustainable development of the biosphere and the harmonious coevolution of man and nature.

The scientific program of the conference included plenary and poster presentations. The total number of presentations was 27. High interest to the event was shown by scientists and researchers from Belarus, Russia, Ukraine, Germany, India, and the United Arab Emirates.

The conference was attended by domestic and foreign representatives of academic and scientific circles, public organizations, and inventors, including guests from Latvia, Estonia, Moldova, Slovakia, Great Britain and Peru.

Based on the results of the II International Scientific and Technical Conference "Non-Rocket Space Industrialization: Problems, Ideas, Projects", the Organizing Committee presented the following Resolution.

1. To stress the importance of further development of the issue of non-rocket near space industrial exploitation.

2. To highlight the importance of the geospace project of planetary scale: the General Planetary Vehicle of engineer Unitsky as the main part of the SpaceWay program on industrial exploitation of the near space at low-Earth equatorial orbits.

3. Taking into account the immensity of the SpaceWay program, to stress the high priority and obvious relevance of development of cooperation between the counties of the world, international organizations, leading global companies, scientific research institutes and universities for implementation of the SpaceWay program.

4. To hold the next III International Conference on problems of non-rocket space exploitation in 2020 in the Republic of Belarus.

5. To recommend considering in future the matter of closer definition of the conference title, which read be as follows: International Scientific and Technical Conference "Non-Rocket Near Space Industrialization: Problems, Ideas, Projects".

6. To establish the EcoSpace Club as a permanent body of the conference.

7. To conduct regular scientific, technical, research and practical workshops on the matters connected with industrial near space exploitation in order to attract more researchers to this topic.

8. To recognize high scientific and scientific technical level of the reports presented at the conference.

9. To publish the collection of scientific articles on the results of the conference. The participants whose papers will be published are to prepare these articles in the form of scientific papers in accordance with the requirements.

The organizing committee expresses its gratitude to all participants of the conference, speakers, foreign guests, sponsors, without whom the holding of this event would be impossible.

The Organizing Committee
21.06.2019

DEAR AUDIENCE!

We will be happy to receive your feedback on the presented materials of this collection of articles. Please send your comments and suggestions to the following e-mail: conf2019@ecospace.org.

Besides, we kindly inform that the III International Scientific and Technical Conference "Non-Rocket Space Industrialization of Near Space: Problems, Ideas, Projects" will take place in 2020. If you are interested in the subject of the planned event and want to participate, please send your applications to the following e-mail: conf2020@ecospace.org.

The conditions to participation are presented on the following website: https://ecospace.org.

To purchase this collection of articles, please contact: conf2019@ecospace.org.

The Organizing Committee of the Conference
and Editorial Board of the Collection of Articles

Glossary of terms and definitions used in the Collection of Articles

DeepSpaceIndustry (program) is a program of industrialization of the deep space, interplanetary and interstellar space, using such space technological, spatial and material resources as asteroids, comets, small and large planets and their satellites, the Sun, other stars, etc.

DeepSpaceIndustry (technology) is development and scaling of the space industry due to the use of such inexhaustible resources of the deep space as technological resources (vacuum, weightlessness, space, other), material resources (mineral, energy, radiation, information resources (each information has a material carrier and source)) and other.

EcoCosmoHouse (ECH) is a space structure with a small (according to the standards of the planet Earth), closed autonomous biosphere, possessing artificial gravity and adjustable in a given range of parameters of the atmosphere and the living environment. The ECH is sufficient for autonomous residence of a human settlement of up to 10,000 people.

EcoCosmoHouse on the planet Earth (ECH-Earth) is an earth structure designed for autonomous and time-unlimited residence of a human settlement of an estimated number, with maintaining in the inner confined space of the conditions for development of the ecosystems with the necessary properties of the planet's biosphere, and with the additional technological processes ensuring the existential human needs: parameters of the atmosphere and living environment, food resources, etc. ECH-Earth is a model of ECH in terms of creating and organizing the internal space and all of its components (biosphere, technology, processes interaction, etc.).

EcoEnergy (program) is a program for the "green" energy development, which includes coal-fired power plants working according to the new logic (producing humus from coal and its waste combustion), solar, wind and hydrogen energy and other energy solutions capable of becoming a part of the geocosmic infrastructure.

EcoEnergy (technology) is a complex of energy technologies using only such sources of raw materials and energy in their processes, which contribute to the overall environmental management, reduce harmful emissions and improve the efficiency of the fuel (raw materials) disposal eliminating the environmental pollution.

EcoSpace program complex (EcoSpace PC) is a complex of EcoSpace programs (environmentally clean world), reflecting the ideology of the EcoSpace Club and prepared for implementation of the following large-scale peaceful space exploration projects: SpaceWay, SpaceIndustry, DeepSpaceIndustry, SkyWay, HyperU, GreenWay, EcoEnergy.

Equatorial Linear City (ELC) is a well-developed network of transport, energy, engineering and IT infrastructures, based on a cluster-type linear city passing along the Earth's equator, including the ports (including sea ports) and the GPV launch flyover, both in land and in maritime versions (built according to the HyperU and SkyWay technologies).

General Planetary Vehicle – GPV – (program) is the geocosmic transport and infrastructure program designed to launch the cargoes into low circular equatorial orbits in order to industrialize the near-Earth space.

General Planetary Vehicle – GPV – (technology) is a giant self-supporting vehicle, a construction of the astroengineering scale (with bigger dimensions in comparison to the planet Earth), providing large-scale cargo and passenger transportation to the near-Earth equatorial orbits and back, based on the only possible (from the viewpoint of physics) environmentally friendly geocosmic transport technology using only internal forces of the system for its movement in space (in the process of operation there are no significant interactions with the environment, either energy, mechanical, chemical, or other interactions).

GreenWay (program) is a program on recreation of various elements of the biosphere using the natural technologies; designing of the surrounding space and the system of organic farming, which are based on interrelations from the natural ecosystems; research and implementation of the environmental solutions in various areas of human life.

GreenWay (technology) is a complex of innovative solutions aimed at the implementation of the rational environmental management, modification of hazardous industries and their replacement with the harmless ones using the natural technologies, manufacturing of products in environmentally closed cycles, elimination of using the synthetic chemicals in agriculture and introduction of the organic biotechnologies in agriculture.

HyperU (program) is a program for creation and development of the network of hyperspeed (aboveground and underground; continental and oceanic) transport complexes (with the speed over 1,000 km/h) on all continents of the planet Earth, built using the HyperU-technologies, which are a kind of string technologies, prestressed and continuous over the length of structures.

HyperU (technology) is implementation of the complex of solutions aimed at creating the hyper-speed transport infrastructure (with the speed over 1,000 km/h) for cargo and passenger transportation in the transport tunnel with rarefied atmosphere.

Industrial Space Necklace "Orbit" (ISN "Orbit") is the linear industrial cluster-type ring encircling the planet Earth in the equatorial plane at the altitudes of 350–500 km. The clusters (industrial, scientific, energy, residential, tourist, agricultural and other) are interconnected by the transport, energy and information communications, and with the planet Earth – by means of a geocosmic vehicle (GPV). ISN "Orbit" has a linear pier for GPV mooring loading/unloading of cargo and boarding/deboarding of passengers.

SkyWay (program) is a program for creation and development of the network of string transport complexes of the "second" level on all continents of the planet Earth and between them, including across the ocean, built according to the SkyWay technologies.

SkyWay (technology) is implementation of the complex of string technologies, which allow to significantly improve the transport infrastructure for the cargo and passenger transportation on the planet from the point of view of minimizing its adverse effects on the biosphere and improving the transport safety, and which ensure effective transportation of people and goods in the future within a single geocosmic transport system, having its branches all over the planet Earth.

SpaceIndustry (program) is a program of industrialization of the near-Earth equatorial orbits: transfer from the planet Earth beyond the biosphere and re-equipment of the environmentally harmful industry with creation of the Industrial Space Necklace "Orbit" (ISN "Orbit") by means of the geocosmic transport represented by the GPV.

SpaceIndustry (technology) is gradual replacement of all the energy-intensive and hazardous to the biosphere industrial enterprises to the enterprises located on the near-Earth orbit, with creation of the orbital transport & infrastructure and industrial & residential complex, covering the planet at the equatorial plane at altitudes of 350–500 km. The technology includes SpaceTransNet (STN) interacting with the General Planetary Vehicle (GPV).

SpaceTransNet (STN) is transport & infrastructure and energy & information network to ensure operation of the Industrial Space Necklace "Orbit" (ISN "Orbit") on the near-Earth orbit.

SpaceWay (program) is a program of non-rocket development of the near space, which includes three independent subprograms aimed at re-equipment and replacing of the environmentally harmful part of the industry from the planet Earth to the near-Earth orbit: Equatorial Linear City (ELC), General Planetary Vehicle (GPV) and SpaceIndustry.

SpaceWay (technology) is creation on the planet Earth of a unified transport and communication infrastructure along the equator to be organized according to the logic of the linear city, which is interconnected with high-speed communications, has branches all over the planet Earth and acts as the basis for functioning of the geocosmic transport system ensuring transportation of raw materials and people for the space industry operation (the SpaceIndustry program), located at the equatorial plane in low circular orbits, as well as the geocosmic transport system itself, represented by the General Planetary Vehicle (GPV).

TransNet (program) is a program to create a global ground-based communication network based on the SkyWay string technologies, which will include transport, energy, information and other nodes and meet the requirements of the XXI century.

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The collection of articles reflects the subject and summary of the reports presented within the framework of the II International Scientific and Technical Conference Non-Rocket Space Industrialization: Problems, Ideas, Projects. The Conference 2019 was dedicated to the topic of solving the global problems of the today's world by space means, the prospects for the industrial development of the near space, the peculiarities of creating the non-rocket geocosmic vehicle, the basic principles of organizing the space settlements with creation of the enclosed self contained biospheres. The collection of articles contains works of the engineers, inventors, scientists, representatives of non-governmental organization from Belarus, and from the near and far-abroad countries.

The publication is intended for the wide audience of readers; is of interest to both a specialized audience and everyone, who thinks about the future of human civilization.

Scientific Publication

NON-ROCKET SPACE INDUSTRIALIZATION: PROBLEMS, IDEAS, PROJECTS

Collection of Articles
of the II International Scientific and Technical Conference

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Signed to print on 22.07.2019. Format 60 × 84 1/8. Enamel paper. Offset printing.
Conventional printed sheets 27.9. Published sheets 25.1. Circulation 1,000 copies. Order 191000.

Ordered by Astroengineering Technologies LLC.

PARADOX LLC
Certificate of state registration of publisher, manufacturer, distributor of printed publications No. 1/221
dated 12.03.2014. 21-25 K. Marksa str., 230030, Minsk. Tel .: +375 (017) 380-43-11.

Printed in the printing house **TM-ARGO-GRAPHICS LLC**
Certificate of state registration of publisher, manufacturer, distributor of printed publications No. 2/95
dated 01.04.2014. 148 Galo str., 230131, Minsk. Tel .: +375 (017) 336-70-51.

UDC 629.78(082)
LBC 39.6я43
ISBN XXX-XXX-XXX-XXX-X

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