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Philosophical frontiers of space exploration: pro et contra

Fronteras filosóficas de la exploración Espacial: pro y contra

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Abstract

We have been living in the "cosmic era" since 1957. Mankind has learned to utilize the near-Earth space for its practical needs. But the rest of outer space is still a mystery to us. The objective of this study is to clarify several main questions: why should humanity explore the extraterrestrial space? what dividends and obstacles await us on this path? which should be ethical and legal aspects for the outer space exploration? In our research we used several methodological instruments: axiological approach, dialectical method, systematic approach, comparative statistical analysis. The article studies general humanitarian dimensions of the problem of space exploration, socio-economic aspects, incentives and technological limits in development of the nearest space objects. A special place is given to research of juridical collisions and legislative gaps in contemporary space law, and ethical

Resumen

Vivimos en la «era cósmica» desde 1957. La humanidad ha aprendido a utilizar el espacio cercano a la Tierra para sus necesidades prácticas. Pero el resto del espacio exterior sigue siendo un misterio para nosotros. El objetivo de este estudio es aclarar varias cuestiones principales: ¿por qué debe la humanidad explorar el espacio extraterrestre? ¿qué dividendos y obstáculos nos esperan en este trayecto? ¿cuáles deben ser los aspectos éticos y jurídicos de la exploración del espacio ultraterrestre? En nuestra investigación utilizamos varios instrumentos metodológicos: enfoque axiológico, método dialéctico, enfoque sistemático, y análisis estadístico comparativo. El artículo estudia las dimensiones humanitarias generales del problema de la exploración del espacio exterior, y los aspectos socioeconómicos, incentivos y límites tecnológicos en la explotación de los objetos cósmicos más cercanos. Se concede

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imperatives in a process of outer space exploration.

Keywords: space exploration, global cooperation, extraterrestrial territories, space law, ethics.

un lugar especial a la investigación de las colisiones jurídicas y las brechas legislativas en el derecho espacial contemporáneo, e imperativos éticos en el proceso de exploración del espacio exterior.

Palabras clave: exploración del espacio, cooperación global, territorios extraterrestres, derecho espacial, ética.

Introduction

Not so long ago, all those interested had a unique opportunity to see an "infrared panorama" of the center of our Milky Way galaxy, including such curious areas as the Quintuplet Cluster, the Arches Cluster (one of the densest star clusters in our Galaxy) and, of course, the area in which the observer is supposed to see the accretion disk formed by the supermassive black hole Sagittarius A* (Murchikova et al., 2019: 83). The image, obtained by combining observations from the SOFIA stratospheric observatory and the American and European "Spitzer" and "Herschel" space telescopes, was first published in 2020 on NASA's website (NASA, 2022). This panorama, spanning a distance of more than 600 light-years, shows details of the center of our Galaxy hidden in dense swirls of gas and dust (EHT, 2022), opening the door to future research on how massive stars form and what fuels the supermassive black hole at the galactic core.

This image, as we can see, became possible 63 years after the beginning of the "space age". During this time, extraterrestrial space has become not only an object of scientific interest, but also a zone for the realization of geopolitical ambitions of the leading powers, and a capital-intensive part of the Earth's economy. The *scientific community* focuses on fundamental research, while *states* regard space exploration as quite utilitarian.

We should draw some attention to existential, epistemological and symbolic themes, in order to underline the connection between the image of the center of the Milky Way galaxy and philosophical reflections. Our limited ability to observe the galactic center (as we cannot see it directly, through optics) demonstrates the limits of human knowledge and perception. This can be tied to *epistemological debates* in philosophy, such as whether true sensual knowledge is more accurate or important compared to theoretical constructs, and how these different types of knowledge influences our understanding of reality. This invites reflection on what it means to know and understand when faced with something as complex and distant as the galactic core. In addition, the center of the Milky Way can be a symbol of both the awe and insignificance experienced by humanity in the face of the vast Universe. This resonates with *existentialist ideas* about finding meaning in an immense, indifferent cosmos. The sheer scale and mysterious nature of the galactic center can reinforce arguments about the human search for new purposes amid cosmic vastness.

Simultaneously, we can try to use the imagery of the Milky Way center as a kind of *metaphor* for human inquiry: the center of the Milky Way galaxy, with its dense star clusters, supermassive black hole (Sagittarius A*), and cosmic dust, symbolizes the profound mysteries of existence. This implies philosophical questions about the nature of the Universe, our place in it, possible expanding of mass consciousness, and the limits of human understanding. For instance, just as astronomers struggle to observe the mentioned area due to cosmic obstructions, philosophers grapple with concepts that are difficult to fully grasp or express. Along the same lines, there are *quite utilitarian* interests and controversies that we will focus on in this research.

How many spacecraft have been launched by mankind as of today? Their number, according to the United Nations Office for Outer Space Affairs (UNOOSA, 2024), is 19124 objects as of September 13, 2024. The dynamics of the increase of such objects in near-Earth space is very remarkable here. Thus, when this study was just beginning (in November 2019), the number of space objects launched by mankind was 8836 (between October 1957 and November 2019), and as of July 2020 it was already 9611 objects (according to the same source). From this statistics we can see that only for the last 4 years about 9500 objects have been launched, which is comparable to the total number of space objects deployed by mankind for the previous 63 years (1957-2020). All these objects belong (in different ratio) to about 100 countries and their private companies, but only about 10 countries of the world possess the whole complex of necessary technologies, infrastructure and specialists, by whose efforts all these items were put into space (using more than 5500 launch vehicles). As of today, the total launch mass of all used launch vehicles has exceeded 2 million tons. The most launches naturally occur in recent years (456 – in 2017, 453 – in 2018, 580 launches in 2019). For the incomplete year 2024, it has already been launched 1635 satellites (mostly 'Starlink') between January 1 and September 13, 2024. But what can these statistics tell us?

The main ***purpose*** of this article is to clarify several questions: *why* should humanity explore extraterrestrial space (what dividends and risks await us on this path)? *where* are the *key consensus points*, the achievement of which will be the determining preconditions for humanity to go beyond the current limits of inhabited space and to establish itself in the outside world? (and what nuances are involved in this process).

Literature Review

The current knowledge on the outer space exploration matters is presented in some publications and research projects. Among these works, we would acknowledge those focused on different groups of issues: resource-centered arguments, existential and anthropological reasons to explore the extraterrestrial bodies, political and societal ties, space and energy technologies advancements, international legal collisions, etc.

The report titled "The Helium-3 shortage: supply, demand, and options for Congress" (Shea & Morgan, 2010) addresses the critical shortage of helium-3, a rare isotope with significant applications in national security, medical imaging, and industrial processes. It outlines the causes of the shortage, primarily linked to the decline in domestic production following the cessation of tritium production for nuclear weapons, and a surge in demand post-9/11 for radiation detection technologies. The report discusses federal responses to the crisis, including rationing schemes developed by an interagency committee and ongoing investigations into alternative sources of helium-3. These sources may include extracting helium-3 from nuclear reactors or recycling existing supplies. Additionally, it highlights that congressional oversight is evolving as lawmakers begin to explore options for increasing supply, reducing demand, and improving allocation processes to address the growing disparity between supply and demand.

The article "Lunar Helium-3 Fuel for Nuclear Fusion: Technology, Economics, and Resources" (Simko & Gray, 2014) discusses the potential of helium-3, an isotope found abundantly on the Moon, as a fuel source for thermonuclear fusion. Helium-3 is considered advantageous for fusion energy production because it is non-radioactive and could result in less harmful waste compared to traditional nuclear fuels, making it a cleaner energy option. The Moon's surface has accumulated helium-3 over billions of years due to solar wind, which poses an opportunity for mining this resource. The article also examines the economic feasibility of extracting helium-3 from the lunar regolith and transporting it back to Earth. It suggests that with advancements in fusion technology and mining techniques, helium-3 could become a competitive energy source, potentially leading to significant reductions in electricity costs. However, the challenges of developing the necessary infrastructure for lunar mining and the high costs associated with space operations remain critical hurdles.

The article "The philosophy of the cosmos as the new universal philosophical teaching about being" (Bazaluk & Kharchenko, 2018) presents a specific philosophical framework that seeks to explore the nature of existence through the lens of cosmology. Key themes include: delving into fundamental questions about being, existence, and the nature of reality, suggesting that insights from cosmology can enrich our understanding of these concepts; possible anthropological niche expansion; merging scientific insights with philosophical inquiry (this approach aims to create a comprehensive worldview that reflects both empirical observations and metaphysical considerations).

The study "Chinese perspectives in the “Space Race” through the prism of global scientific and technological leadership" (Svyrydenko & Stovpets, 2020) examines China's ambitions and strategies in the contemporary space exploration, contrasting them with established 'space powers'. It highlights how China's space program serves as a vehicle for achieving national goals, including technological advancement and international prestige, encapsulated in the concept of the "Chinese Dream". The analysis situates China's space endeavors within the broader geopolitical landscape, emphasizing its aspirations to assert itself as a leader in global science and technology. The paper provides a brief history of China's space achievements, showcasing milestones that reflect its growing capabilities and ambitions. Philosophical underpinnings of China's approach to space exploration are linked to national aspirations for global influence.

Today, there is no doubt that China is among the new world leaders in space exploration (being the next after the USA). But a logical question arises, what civilizational qualities have brought this country to the leading position? The article "Sinitic civilization's worldview features and their system-forming role in the complex of social relations in modern China" (Stovpets, 2020) encompasses a complex set of beliefs and values that have historically shaped social relations in modern China. This worldview is characterized by several key features, including a strong emphasis on collectivism, diligence, and the importance of state paternalism and social hierarchy. These elements contribute to the societal fabric, influencing everything: from governance to interpersonal relationships, and of course China's external positioning as a technological leader, with *its own space program*. In contemporary China, the Sinitic worldview plays a system-forming role by reinforcing social cohesion and stability, which is crucial in a rapidly changing world. The integration of traditional values with modern practices and technological advancements reflects the resilience of this worldview, demonstrating its adaptability in addressing contemporary challenges while maintaining cultural continuity. Simultaneously, there is an obvious Chinese commitment to expanding their global influence by pushing forward in the field of advanced scientific research. Cosmos is among these undoubted priorities. Overall, the study presents a comprehensive view of how China perceives its role in the evolving dynamics of global leadership and competition. Such cross-cultural insights are useful for studying national public opinion, illustrating how societal values oppose or align with space exploration efforts.

The article "Educational marketing as a basis for the development of modern Ukrainian society and the state" (Borinshtein et al., 2022) focuses on enhancing educational marketing as a crucial component for fostering social-economic development of Ukraine. It argues that effective educational marketing strategies can significantly strengthen the intellectual potential of Ukrainian society and support the state's development goals, enshrined in sectoral industries (e.g. aerospace construction, rocket science, microchip manufacturing, drone production, and polytechnic studies). The research also identifies various challenges faced by the contemporary education system: infrastructural, financial, and organizational issues, particularly in the face of ongoing higher education reform. It proposes a renewed educational marketing strategy tailored to address these challenges, emphasizing the need for higher education institutions to cultivate marketing skills among students to improve employability and competitiveness in both national and global contexts. The study also highlights the importance of aligning educational services with market demands to ensure that graduates possess the necessary competencies for successful integration into society and the labor market. Societal investments into the educational realm, and changing approaches to educational marketing may raise the level of existing technological sectors, *preserving Ukraine's place* among "spacefaring nations".

The issues of rivalry between the advanced powers for extraterrestrial resources (in particular, for helium-3 contained in the lunar regolith) are directly related to the success of the ITER project. In the fusion research environment, reports of constant shifts and delays in the completion of ITER construction, not to mention exceeding the initial budget, have drawn attention (Banks, 2024). ITER, or International Thermonuclear Experimental Reactor, is a toroidal facility for magnetic confinement of plasma to achieve the conditions necessary for controlled thermonuclear fusion to proceed. ITER's mission is to demonstrate *the feasibility of commercial use* of a fusion reaction, and to address the physical and engineering challenges that encounter along the way. And once all these problems are solved, there will be serious competition between leading space powers for the priority right to extract helium-3 from the lunar soil. This will require more detailed geopolitical agreements, as well as clarification of existing norms of international space law.

We will further refer to these and other related sources in subsequent sections of this study.

Methodology

In our research we used several methodological instruments: axiological approach, dialectical method, systematic approach, comparative statistical analysis.

The axiological approach (when applied to space exploration issues) focuses on understanding the values and ethics underlying 'earthly relations' between nations, states, and societies involved in the 'space race'. It helps to identify and analyze the values inherent in arguments for and against space exploration (e.g. advancements in fundamental science, human curiosity, the pursuit of knowledge, raising sustainability, sharing interests of resource allocation, exacerbation of technological and geopolitical competition). It also makes us to reflect on questions of balance between competing values such as the potential benefits to humanity (e.g. technological & scientific progress, future colonization of the nearest celestial bodies) versus potential ethical and natural concerns (e.g. the risk of ecological harm to extraterrestrial environments, and the prioritization of space exploration over urgent earthly human needs). After all, the axiological approach gives us the possibility to evaluate the moral and philosophical implications of space exploration, considering questions like whether resources should be used for exploration of extraterrestrial realms, or addressing Earth's challenges first.

The dialectical method (as it involves the exploration of ideas through dialogue, aiming to understand disagreements and reach a consensus) helps us to weigh up the arguments in favor of tenacious space exploration (like ensuring humanity's long-term survival due to additional energy resources, mastering an alternative living space, advancing cosmic science & aerospace engineering), and counterarguments against it (e.g. too high costs of space missions, increasing unresolved social issues on Earth, the risk of weaponizing of the near-Earth space). Being engaged in a reasoned exchange, proponents and critics may challenge each other's views, exposing underlying assumptions and outlining areas of agreement on fair rules regarding space exploration.

The systematic approach in our research gives the opportunity to organize complex information from the realm of astrophysical research - into structured frameworks for comprehensive analysis. Inside the systematic approach, we should mark the *holistic analysis*, which enables us to look at space exploration process as a system interconnected with technological, social, economic, legal, ethical and philosophical dimensions. This approach considers the meaning of acting interrelationships: how the aforementioned dimensions interact, in particular, which is the correlation between the funding of space programs and societal priorities, what is the true impact of space technology on global progress, extraterrestrial ecology, international safety, geopolitical stability on Earth, and so on.

While less philosophical in its nature, *comparative statistical analysis* provides us with valuable empirical insights relevant to the dynamics of space exploration. Using the method of data-driven evaluation, comparative statistical analysis helps us to compare affordable public information related to investments in space exploration versus outcomes (e.g. scientific advancements, technological spin-offs). By analyzing how countries with active space programs fare compared to those without (in terms of economic growth or technological development), we can infer their potential benefits and drawbacks. Finally, the results of use of such an instrument as the comparative statistical analysis, in this research, are visualized as the table and the diagram describing the UNOOSA statistics for the objects launched by mankind into outer space between October 1957 & September 2024. It makes us see how the priorities and aerospace capabilities of mankind were changing over time:

Table1.
Objects launched into space in the period of 1957-2024

Period	Objects Launched	Change from Previous Period
Oct 1957 – Dec 2016	7347	-
Oct 1957 – Dec 2017	7803	+456
Oct 1957 – Dec 2018	8256	+453
Oct 1957 – Nov 2019	8836	+580
Oct 1957 – Jul 2020	9611	+775
Oct 1957 – Sep 2024	19124	+9513

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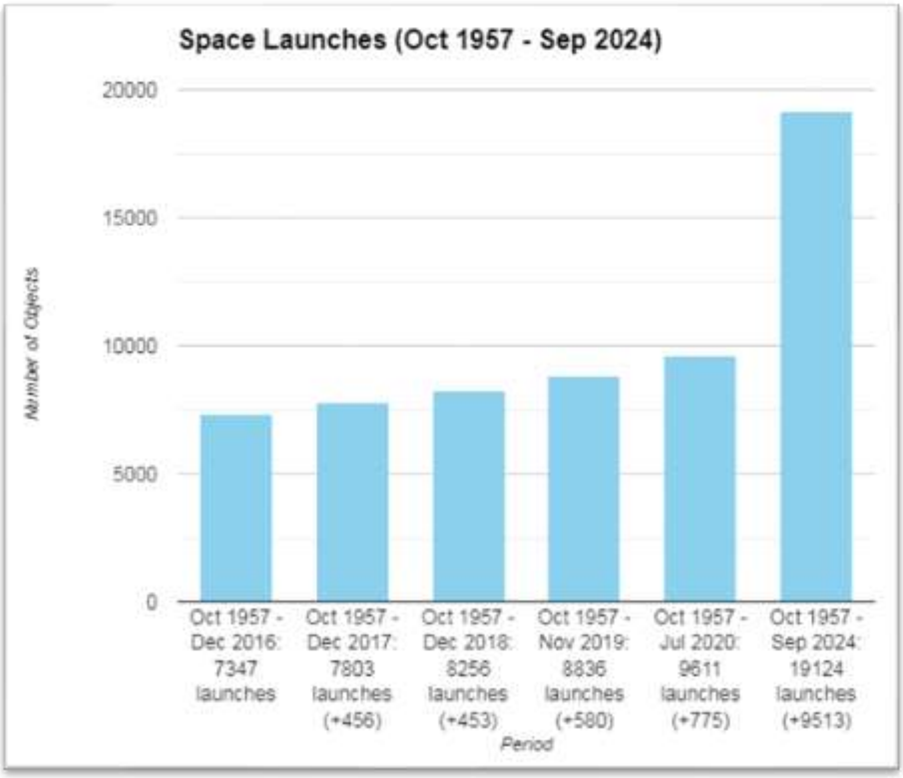

Chart 1. The description of space launches dynamics between 1957-2024

Results and Discussion

Limitations of the study in respect of Space Exploration

Despite the significant advancements made for the last decade in astrophysical research, there are inherent limitations that hamper related studies and impede the movement of progress in space exploration. Among other issues, there are those which constrain the scope and depth of any study related to the center of the Milky Way galaxy. These limitations can impact our understanding and interpretation of data, shaping philosophical and scientific discussions alike. Here we are talking about technological constraints, physical barriers, data interpretation challenges, resource and funding limitations, and theoretical gaps in fundamental science.

Technological constraints are mainly connected with the fact that current space research relies on telescopes and space probes with certain technical limits. Instruments such as the Hubble Space Telescope or the more advanced James Webb Space Telescope have significantly improved our capacity to observe 'deep space'. However, their resolutions and sensitivities still fall short when capturing intricate details of the densely packed and obscured regions at the galactic center. The presence of cosmic dust and gas, along with immense distances, challenges our ability to obtain clear, unambiguous images and data.

Physical barriers are naturally conditioned by the fact that the core of the Milky Way galaxy is located approximately 26,000 light-years away from Earth (Abuter et al., 2019) and is surrounded by interstellar dust clouds that block visible light. While infrared and radio wave technology allows us to partially bypass these obstacles, this methodology still has its limitations. The complex interplay between various wavelengths, interference, and the need for precise calibration all pose significant hurdles, potentially skewing or limiting the correct data we can gather.

Data interpretation challenges are due to the situation that even when various data can be collected, interpreting it accurately requires overcoming inherent ambiguities. High-energy phenomena, such as those produced by the supermassive black hole Sagittarius A* and surrounding stellar objects, create complex patterns of electromagnetic radiation. Differentiating between overlapping signals and disentangling noise from meaningful information is a significant task that can lead to misinterpretations or uncertainties in the study's conclusions.

Resource and funding limitations are also obvious, as Space research is often constrained by budgetary and logistical challenges. Funding for space missions and modern observatories must compete with various scientific and non-scientific priorities, leading to potential compromises in the comprehensiveness of data collection and analysis. This huge financial pressure can hinder the ability to conduct repeated or extended studies that might otherwise yield more thorough results.

Theoretical gaps in contemporary astrophysical science are an equally significant obstacle. Even with the data available, our theoretical models of how galactic centers behave remain incomplete. Still, many of them are just models and assumptions. In addition, the extreme gravitational and electromagnetic conditions found in the heart of the Milky Way push the boundaries of current astrophysical theories, such as general relativity and quantum mechanics. This also limits our ability to predict and fully understand the nature of phenomena observed within the mentioned cosmic region.

General humanitarian dimensions of the problem of space exploration

Mankind (at least its advanced part) has long been obsessed with the idea of unraveling the mysteries of the cosmos. But, as on all other key issues that exist in science, in sociocultural practice, in life generally, there is no consensus neither on the prospects, goals and objectives of so-called space activities, nor on the tools and technologies for their realization, nor on the limits of admissibility of human intervention in the existential mysteries of the Universe.

Philosophy poses a number of questions to all mankind, that implicitly contains such a question, the answer to which predetermines the whole further strategy in relation to the problem under study. Using Aristotle's terminology, it is necessary to designate "the final cause", a "target reason". After that, our question (in projection to space activity) can sound as follows: is it *necessary* to explore space at all – not just to study it, but to practically exploit it, attempting to colonize the nearest celestial bodies? And if "yes", then *for what* do we need (with such difficulties) to go beyond the limits of our familiar terrestrial world?

It is evident that, firstly, we have not yet unlocked all the codes and mysteries of *our* planet. And we are still far from exhausting its natural resources. Moreover, the invention of new energy sources, land recultivation, recycling and other smart technologies are pushing these exhaustion threats even further away. Secondly, different civilizations of the Earth have not yet learned to live in peace and harmony, without wars, violence, extortion and mutual intimidation, not to mention the enormous socio-economic and cultural stratification of mankind. So, maybe it would be more expedient to invest funds and common efforts in establishing wellbeing *here* on Earth?

Proponents of active space exploration counter-argue: the keys to the secrets of the Earth, to unraveling the mysteries of the origin of life in general (and man as a special case) lie *beyond* our planet, in the Universe. Therefore, the study and gradual exploration of space seems to bring several useful effects at once: it increases our cognitive abilities, it can contribute to the further development of *noosphere* (and consolidation of mankind on *this* basis), it expands the experimental field of science, contributes to the qualitative growth of empirical arrays of knowledge about outer space and cosmic bodies, it may have a significant resource potential and can serve as a kind of alternative to Earth's natural resources in case of their exhaustion, etc. All these are, more or less, *pragmatic* aspects of space activities.

But there are also *metaphysical* aspects in people's aspiration to explore any extraterrestrial spaces. After all, by going beyond the limits of the present inhabited space, man is as if attempting to encroach upon the pre-established "earthly order of things", and is trying to prove to himself the ability to build (in the literal sense) new worlds outside our traditional Earthly abode. Beyond this abode, there are new opportunities (for the beginning, at least those material resources, which are rare on Earth, but are abundant in the lunar soil, that will be discussed in more detail below).

At the same time, other kinds of questions arise here. For example, how "mature" is our contemporary civilization? And if we accept the pattern that an "over-mature" civilization expands its resource basis to the maximum, won't it happen that this new "cosmic" spiral in the flourishing of technical genius will be the beginning of a further decline of civilization? Some related aspects on possible future scenarios of the human development were studied before (Stovpets et al., 2023) in the light of digital technologies surge.

Opponents (in philosophy) to an active exploration of space do not share any optimistic belief in the co-evolution of the biosphere and sociosphere; they are rather skeptical about further development of such a co-evolution process, which would make *the prospect of colonization of extraterrestrial spaces* just a little more realistic. These doubts are caused, among other things, by the realization of the obvious immeasurability of the scale of human civilization - with the boundlessness of space and time, with the cosmic expanses of the Universe.

But if we accept the aforementioned *prospect* as highly probable, then our former “anthropic niche” is significantly expanded. The process of reconstructing the “human niche” will need to be understood in an evolutionary context, taking into account the synthesis of ecological, biological and social landscapes, which will no longer be appropriate to consider as separate spheres (Fuentes, 2015: 305).

Legal issues in the field of space exploration have as their main prerequisite a general mistrust in the international public consciousness that the exploration of near-Earth space will have exclusively *peaceful* purposes, and will pursue only *pure scientific* and *common humanitarian* interests. This mistrust stems from the entire previous history of human civilization, and relies upon various geopolitical fears and uncertainties. This global disbelief is reflected even in the very names of the existing legal acts regulating the procedure of so-called space activities. We will talk separately about the legislative sources, which, according to the general idea, should regulate the use of extraterrestrial space and safeguard space activities. They contain a variety of contradictory points.

The *socio-economic prospects* for active space exploration are still unclear. Science will undoubtedly benefit from any research in this area. But will the world economy benefit? And national economies? After all, national ambitions and geopolitical rivalry often lead to the depletion of state budgets. Especially if an "arms race" starts (as it has already happened many times) in an attempt to gain strategic dominance, and ensure economic and military-political hegemony, including through the militarization of near-Earth space. Meanwhile, economic strategies of many mighty nations directly or indirectly mention *space exploration* as a promising way of their own technological development and building mutually beneficial international cooperation. Moreover, in the *worldview* of some civilizations (Stovpets, 2020) there is a commitment to expanding their global influence by pushing forward in the field of advanced scientific research. Cosmos is among these undoubted priorities.

Some nations succeed (Svyrydenko & Stovpets, 2020), and the quality of their people's life may increase, while others do not, and then there is a large risk of social crises with poorly predictable consequences. In the context of globality, this situation is (to a different extent) *harmful to all humans*. Besides, today there are *no guarantees* that the development of extraterrestrial resources - even on the space bodies closest to the Earth - can be at least somewhat profitable, for objective reasons (huge distances, mining conditions, lack of technology or extreme costliness of technologies for the extraction of these resources and their delivery to the Earth, as well as their safety for the Earth's biosphere, and other problems that we *may not even be aware of* yet).

Although in general it is still clear that the *colonization* of other planets, in terms of its feasibility at current stage of development of our civilization, is on a par with the search for eternal life. This ideology is cultivated by the so-called “immortalist” congregation, which sets the task of achieving artificial immortality. Transhumanist discourse is *related* to the theme of exploration of extraterrestrial spaces. Since, probably, only such a radical expansion of the limits of technology interference in human nature - as transhumanists propose - in case of success, will allow us to talk seriously about the possibility of *colonization* of the nearest space bodies. A more detailed analysis of the problems of transhumanism (including reflections on the doctrines of creation, enhancement, and immortality) is reflected in other publications (Farman, 2013: 740).

It seems to us that the above arguments and counterarguments regarding active *space exploration* are sufficient justification for the relevance of this study. However, the existing contradictions encourage us to reveal in more detail the ethical, legal, political, socio-economic, technological facets of the nowadays space exploration activities of mankind, with an attempt to identify the main controversies and possible points of consensus.

Socio-economic aspects of the nearest space objects exploration. Technological limits and incentives to overcome them

Some publications (Carter, 1973; Runcorn & Coleman, 1977), apparently inspired by the incredible progress in near-Earth space research of that era, have suggested that humanity has reached the point beyond which *space exploration* begins. This is particularly true of the Moon, probably the only space object in the solar system that could become an extraterrestrial territory interesting for colonization as early as *this* century.

At the same time, the development of space technology, which had slowed down by the early 1980s, does not allow us to think that space colonization is an easily achievable and, in all cases, reasonable goal. Certainly, due to its proximity to Earth (three days' flight time) and a fairly well-studied landscape, the Moon has long been regarded as the first extraterrestrial territory for the establishment of a human colony. And although back in the last century the Soviet and American lunar exploration programs, being very expensive projects, demonstrated the practical feasibility of flying and landing on the Moon, they significantly tempered the enthusiasm for the immediate establishment of lunar colonies.

Yes, indeed, there are some potential advantages in the exploration of the Moon. We mean its *resource potential*, and the role of a kind of “hub” or “*springboard*” for long-distance space expeditions, and the possibility (though very much postponed in time) of colonization in the case of critical overpopulation of the Earth, and the creation of a powerful *scientific platform* on the Moon *for observations* of the so-called “deep cosmos” (i.e. interstellar medium, other galaxies, astronomical radio sources like the Galactic Center, planetary nebulae, supernovae, pulsars, galaxy superclusters, intergalactic space, other matter of the Universe)... For scientists, the lunar base would be a unique place for scientific research in the fields of planetology, astronomy, cosmology, space biology. The study of the *lunar crust* itself would help answer the most important questions about the origin and further evolution of the Solar system, the Earth-Moon system, and the emergence of terrestrial life.

The absence of an atmosphere and lower gravity (six times less than the Earth's) make it possible to build observatories equipped with the latest optical and radio telescopes on the lunar surface. Because of these conditions on the Moon, such telescopes will be able to obtain much more detailed and clearer images of distant areas of the Universe, much more accurate than it is possible on Earth. Due to the absence of the influence of the Earth's atmosphere, the resolution of such a telescope will be 7-10 times higher than that of a similar telescope located on Earth (Spitzer, 1990). At the same time, it would be much easier and cheaper to maintain and modernize such Moon-based observatories than the currently operating *orbital* observatories.

Vacuum and the availability of cheaper solar energy open new horizons in the fields of electronics, metallurgy, metalworking and materials science. In fact, the conditions for metal processing and creation of microelectronic devices *on Earth* are actually less favorable due to the large amount of free oxygen in the atmosphere, which deteriorates the quality of casting and welding, and makes it impossible to obtain ultra-pure alloys and microchip substrates in large volumes. But in the conditions of the Moon this problem is solvable.

It is known that the Moon possesses a variety of minerals, including metals valuable for industry – iron, aluminum, titanium. Currently, the world's leading technological universities are working on methods of industrial production (in lunar conditions) of the metals discovered, by removing them from the *regolith* – the surface layer of loose lunar soil. What is important for a hypothetical lunar base, in 2009 deposits of water ice were found for the first time in the area of the Cabeus crater near the south pole of the Moon (LCROSS, 2009).

But the main attractor among all known lunar resources is an isotope rare on Earth, helium-3, accumulated in the regolith over billions of years as a result of the outflow of helium-hydrogen plasma – ionized particles also known as “solar wind” – from the solar corona. Helium-3 is now considered *the fuel of the future* because it is planned for use in the thermonuclear reactors (fusion reactors) that will probably replace current nuclear reactors. Many studies have been devoted to the prospects of helium-3, in particular: on the potential applications of helium-3 and the main sources of its obtaining today (Shea & Morgan, 2010), on the possible cost of helium-3 under contemporary conditions (Simko & Gray, 2014), on the approximate helium-3 reserves in the lunar regolith (Slyuta et al., 2007), on the selenographic distribution of this isotope (Schmitt et al., 2017), on some liquefaction technologies enabling the condensation of pure helium-3 (London, 1949 ; Zhelev et al., 2017). So what are the biggest challenges of using *helium-3*, and what are its advantages?

If we ignore the current problem of *feasibility* of controlled thermonuclear reactions in reactors with such fuel, – and the first fusion reactor will not be built before 2034 (Banks, 2024), though the first deuterium plasma is expected to be obtained in 2025 (ITER project, 2016), – the main problem remains the very reality of helium isotope *extraction* from regolith. Based on the above-mentioned studies, the helium-3 concentration in the lunar regolith is about 1 gram per 100 tons. Therefore, to extract *just one ton of this isotope*, at least 100 million tons of lunar soil must be processed in situ! And this is only one of the technological challenges.

Hypothetically, when 1 ton of helium-3 reacts with 0.67 tons of deuterium, this fusion releases energy equivalent to burning 15 million tons of oil (London, 1949, p. 695). The Moon, which has no atmosphere, retains significant amounts of helium-3 in its surface layer, with some estimates ranging from 500 000 tons to 2.5 million tons (Slyuta et al., 2007). If these estimates are correct, then our planet's population could have enough lunar helium-3 resources for about *five millennia* at the current rate of energy consumption (according to maximum calculations). And the most important *environmental aspect* here is that helium-3 does not produce long-lived radioactive waste. Therefore, the problem of their disposal, which is so acute in the operation of nuclear reactors (based on the fission of heavy uranium nuclei) disappears by itself.

However, at present, the technical possibility of the most energy-efficient thermonuclear reaction “deuterium + helium-3” has not been fully studied. The fact is that fusion of nuclei of such isotopes as deuterium, tritium, helium-3, which gives energy yield, is possible only when they are in the state of plasma. And in order for plasma to be stable, it needs a huge temperature, and large values of pressure and density. The main problem of current thermonuclear technologies (realized in experimental reactors) is that *almost all* the energy obtained in the course of a fusion reaction *is spent* to hold the plasma in place (Peacock et al., 1969: 489). For this reason, helium-3 fusion reactors are considered a technology of the distant future.

Another technological challenge will be the creation of a cost-effective transportation system in case the decision to develop the Moon's resources is made. Because sending launch vehicles (boosters) from Earth to the Moon and back is unprofitable; with such costs, extraction of any resources is unlikely to be economically expedient. So, these boosters, together with transportation (cargo) modules, will have to be assembled in Earth orbit. According to some NASA specialists (Rubio & Bowman, 2024), the experience of assembling and operating the International Space Station may be useful here.

But no matter how large the carrying capacity of the transport module, probably to reduce the risk of losing the expensive resource, the mass of each batch of helium-3 extracted on the Moon and transported to Earth will be less than a hundred kilograms, which, at average prices in the global energy sector, is approximately equivalent to 140 million U.S. dollars (Schmitt et al., 2017: 6). In any case, the optimal shipment weight will be determined taking into account not only technical limits, but also the requirements of customers (and the latter will probably take care of *insurance* of possible risks using quite *earthly* legal instruments). The development of such a specific insurance sector is another socio-economically useful effect from the exploitation of the resource base of an extraterrestrial space object.

In addition to all the above-mentioned aspects of extraterrestrial space exploration (technical-technological, socio-economic, private-law aspects) there are unresolved issues of *public-law* nature. The lack of consensus on many of them creates serious obstacles in the peaceful exploration of outer space, and lays the foundations for geopolitical and general humanitarian contradictions in the future, when the exploration of extraterrestrial territories will enter a more intensive phase.

Juridical collisions and legislative gaps in contemporary space law. Ethical imperatives in the process of outer space exploration

The Cosmos and man's place in it have probably been the subjects of reflection at all times of philosophy's development. In any case, we can agree with the thesis that philosophical knowledge, since antiquity, has served as a basis for a holistic worldview, integrating ontological aspects of human existence at the personal, social and cosmic levels (Bazaluk & Kharchenko, 2018: 10). However, jurisprudence (and even such a specific branch as *space law*) thinks in more down-to-earth categories.

In addition to the traditional issues of international space law – prevention of militarization of near-Earth space, prohibition of deployment of nuclear and other weapons of mass destruction in outer space, responsibility of states for the operation of launched space objects, inviolability of property rights to these objects – many other questions arise: what control over territories on other space bodies can be established, and what should be the limits of such control? who owns the resources extracted in extraterrestrial spaces? how to avoid conflicts among states over resources? how to properly organize licensing of space activities (who should carry it out, and what mandatory criteria for granting licenses for the development of extraterrestrial territories should be introduced)? how to protect intellectual property in space (i.e. where is the line between science and commerce)? how to solve the problem of waste disposal, which will inevitably accumulate as further the exploration of extraterrestrial space proceeds? and many other issues that are either insufficient regulated or unsettled at all.

These questions, for the most part, lie in the practical plane of human existentiality. How they are resolved will determine whether the cosmos becomes a source of new opportunities and future prosperity for all mankind, or additional instrument of influence and world dominance for some polities (and a new threat to the others).

We should say that the global agreement on cosmos (Kopal, 1967) declares freedom of any scientific research of peaceful nature in outer space, and names the basic principles of space activities, however it does not provide for instruments of control over their fulfillment or any system of sanctions for their violation. Although Article II of the Treaty establishes the provision that outer space, including the Moon and other celestial bodies, shall not be subject to national appropriation, whether by claim of sovereignty over them, neither by use or occupation, nor by any other means, but this declaration may in fact conflict with Article VIII of the same treaty. It enshrines that a state-party in the Treaty, whose registry includes an object launched into outer space, retains jurisdiction and control over such an object and over any crew of that object during their stay in outer space, and also on a celestial body.

The ownership rights on cosmic objects launched into outer space, including items delivered or constructed on a celestial body and their component parts, remain inalienable while they do exist in outer space or on a celestial body. This means that in the case of a station built on the Moon with all its facilities, which will remain there for any number of years, it will be recognized the national law of the host state in respect of that Moon-based station. Thus, the host-state sovereignty *de facto will extend* to the entire development territory of a certain lunar site (Bagrov, 2019: 29).

Taking into account the high probability of further activities' intensification of the leading space powers beyond near-Earth space, an Agreement on the activities of states on the Moon and other celestial bodies was elaborated within the framework of the United Nations (United Nations Treaty Series, 1979). It stipulates in more detail the principles of scientific and economic activity on the Moon. In particular, Article 8.1 of the Treaty declares that the participating states may carry out their activities on the exploration and use of the Moon at any place on its surface or subsoil. If we think carefully about it, this provision itself becomes a conflictogenic premise in case the economic activities on the Moon will be intensified.

The point is that there are areas on the surface of the Moon that are of particular interest for the placement of long-term stations in them. These include some mountain peaks in the near-polar regions of the Moon, which according to a number of research studies (Sanderson, 2007; Girish & Aranya, 2012: 371) are almost never shaded. Consequently, it's most favorable to place power plants made of solar panels with batteries in mentioned areas. Also interesting are the locations of natural cavities under the surface of the Moon, where it is possible to place manned stations without a risk of exposing them to cosmic radiation. The latter is a significant problem for humans, as the Moon is deprived of a magnetic field that could attenuate powerful radiation flows from outer space.

The legal side of the issue boils down to the fact that Article 8.1 of the mentioned Treaty provides for the unlimited right of states to place their stations wherever they deem necessary. This, on the one hand, contradicts the basic principle of inadmissibility of claims by any state to extend its sovereignty over any celestial body. On the other hand, this naturally creates preferences for the advanced space powers, which will definitely begin colonization of the Moon before others. It is probably because of the ambiguity of The Moon Treaty (United Nations Treaty Series, 1979) that it has not yet been ratified by any of the G7 states, any of the permanent members of the UN Security Council, or indeed any of the countries with their own space program.

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Nevertheless, some countries view the space industry not so much as a means of accessing lunar resources, but mainly as a driver of their *terrestrial* socio-economic potential. For example, the Law of Ukraine "On Space Activity" states that space activity is aimed, among other things, at "...the development of space science and engineering, space services and technologies that contribute to the stable growth of the national economy; the creation of a strong export potential of the space industry" (Law No. 502/96-BP, 1996: clause 3). And in fact, despite a lot of internal and external problems of different nature, until 2022 (the beginning of the full-scale Russian military invasion) Ukraine participated in several international space programs, delivering various engineering & construction works and aerospace services for the European Space Agency (ESA), for NASA and other space industry partners (NKAU, 2024). The Ukrainian State is still the main owner of all sectoral enterprises and plants in the country. New tasks, which demand solution in national aerospace industries, and perspectives of space activities in Ukraine were formulated in the analytical document "Space Vision of Ukraine, 2020-2029" (Committee on Space Policy and Legislation of the Cosmos Association, 2019), and were also specified in the "Concept of the State Space Policy Realization for the period to 2032" (State Space Agency of Ukraine, SSAU, 2011).

Advancement in space exploration must be paired with a profound reform of the education system and sectoral research programs (including project management, aerospace construction, rocket science, and polytechnic studies). Some of these issues regarding necessary educational reforms have already been addressed in our previous studies (Borinshtein et al., 2022). Ukraine is still among those very few countries capable of participating in space launches. This is hardly an achievement of modern Ukraine, but rather a result of the Soviet space legacy. Unfortunately, the current Russian-Ukrainian war severely diminishes Ukraine's chances of restoring itself as an influential 'space country' (as it *was* inside the Soviet Union), where aerospace technology really was at a very high level. Nonetheless, Ukraine *still retains* its applied-science and rocket-building potential, despite the fact that Ukrainian space-industry infrastructure is under military attack.

Returning to the public-law issues of space exploration, it is impossible to ignore the problem of territorial claims on the part of states that plan to establish their bases (for example, on the Moon), as well as on the part of private entrepreneurs and legal entities that, being under the jurisdiction of these states, will be related to "lunar programs". A significant part of geopolitical contradictions can be removed if *the UN* will be the licensor of any kind of activity on commercial exploration of the Moon, and if the developed territory will be provided to licensees of any states not as property, but for *time-limited use* (with the indication of specific time limits). Legal mechanisms may vary, but it is obvious that scientific and economic activities on licensed extraterrestrial territory should *not* take place outside the "terrestrial" legal framework. States under whose jurisdiction entities engaged in the development of extraterrestrial territory are operating, quite naturally, will be guarantors of their residents' compliance with international cosmic legislation.

Finally, another general humanitarian imperative related to Space exploration lies in the realm of *ecology*. On Earth, we have already faced the ecological consequences of garbage accumulation, which natural recreational mechanisms cannot cope with. However, for instance, *on the Moon*, where there are *no such mechanisms at all*, the problem of waste utilization will have to be solved from the very first steps of its exploration. The abandoned malfunctioning mechanism will lie on the surface of the Moon for million years in an unchanged state. And during the period of intensive mining activities on the licensed territory, a huge amount of waste can accumulate, so it is absolutely inadmissible that they form garbage dumps and slag heaps after mineral extraction. Therefore, as unconditional restriction on the extraction of lunar resources (as an example) should be the obligation to fully utilize by-product waste. The license for space activities should clearly stipulate the absolute prohibition of accumulation of unprocessed waste, and ensure serious real sanctions for violation of this principle by licensed companies.

Conclusions

This study allows us to draw some inferences regarding the prospects of *space exploration* and those controversies – philosophical, political, legal, socio-economic, general humanitarian – that are already being identified today in the realm of space activities, and apparently will continue to gain momentum.

Virtually no one denies that the universally recognized global task is to fix the ecological and social situation *here on Earth*. And in such a context, the question naturally arises, *why* spend billions of money on a risky venture to develop much more aggressive extraterrestrial spaces, if right here and now, on the globe, there are undeveloped areas? These terrestrial areas are incredibly vast, and they are evidently *closer* to our earthly life.

Perhaps it is not just "cosmic romantics", and it's not only about deposits of rare minerals. Humans continue to treat the Nature on our planet in a consumerist manner, yet we "rely" on the Moon (or even Mars). It is much easier to build "cosmic dreams" instead of trying to make a real plan how to improve the situation on Earth, and even more so – to follow this plan in real life, abandoning national geopolitical ambitions. Although, the Moon can hardly become a dwelling place for mankind. With a favorable turn of events, it can be a raw material base with few settlements, as well as a scientific and experimental site, and a buffer zone for long-distance space expeditions.

At the same time, *comprehensive space research* and probably the establishment of experimental settlements on the Moon (and later on Mars) should not be abandoned. Though, humanity will have to develop well-coordinated policy for the safe exploration of cosmic bodies. It is necessary to subject the whole range of space activities to detailed international legal regulation, starting with environmental issues (in particular, the problems of waste recycling after extractive industry) and UN licensing of any commercial activities on extraterrestrial territories. Full control over the implementation of all these laws should be transferred to a special committee of the UN, which will be able to grant licenses for the development of extraterrestrial territories, with the right to revoke them if the licensee violates the terms of the license.

The political and economic interests of certain states in space exploration and development should not dominate over the security interests of *all mankind* and cannot violate the principles of general humanitarian well-being. The technological superiority of today's leading space powers should not call into question the right of *developing countries* to participate as much as possible in the exploration of extraterrestrial territories, and *the right of all countries* to receive socio-economic dividends in proportion to their intellectual, financial, material or other contributions.

How soon this cultural-historical cycle can enter into play is hardly known today. However, it is more or less clear that its beginning will actualize a situation when not only research (cosmic observation, cognition of outer space), but also its *exploration* (partial colonization and exploitation) will become a *reality*. Nevertheless, we believe that such a reality must be preceded by a substantial harmonization of life *on our planet*. We consider that the potential *here* is far from being exhausted.

Space exploration represents one of humanity's most ambitious and forward-looking endeavors, offering unparalleled opportunities to expand our knowledge, innovate, and secure a sustainable future. Achieving its full potential, however, *requires different Nations to collaborate on a global scale*. As no single nation has the financial, technological, or sufficient human resources to tackle the immense challenges of space exploration independently. Common goals, shared resources, and collaborative missions – such as the International Space Station – demonstrate how pooling expertise and joint efforts can achieve *what no one country could alone*. Cooperative ventures allow for the sharing of costs, risks, and rewards, maximizing the impact of investments in such a complex activity as the exploration of outer space.

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