SPACE BIOLOGY, SPACE MEDICINE AND SPACE PSYCHOLOGY IN THE CONTEXT OF "HUMAN SCIENCES"

Tereshkova VV[1], Tereshkova EA[2], Firsov DE[3] ✉

[1] The State Duma of the Federal Assembly of the Russian Federation, Moscow, Russia

[2] Tereshkova Charitable Foundation, Moscow, Russia

[3] Institute of Psychology, Sociology and Bioethics, Yaroslavl State Medical University, Yaroslavl, Russia

Human spaceflight involves several risks that significantly impact the future of space programs. Space radiation, weightlessness, loss of muscle mass, hearing impairment, etc. have significant negative effects on the human body in space environment. Additional questions are associated with inevitable evolution of human-machine interaction in those areas where the presence of a researcher is hardly possible yet. Thus, advancements in biology, medicine, and psychology significantly contribute to the success of space projects by addressing the human adaptation to spaceflight both in physiological and spiritual terms. The potential of space biology, space medicine, and space psychology as "human sciences" shapes the future of scientific research and practical solutions for the exploration of near and far space based on extensive data both on physiological and psychological capabilities of humans, and their spiritual resources, which together determine the ability to adapt to a new physical and cultural reality.

Keywords: space biology, space medicine, space psychology, **"**human sciences**"**, spiritual resources

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✉ **Correspondence should be addressed:** Denis E. Firsov
Revolutsionnaya St., 5, Yaroslavl, 150000, Russia; f300670@mail.ru

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КОСМИЧЕСКАЯ БИОЛОГИЯ, КОСМИЧЕСКАЯ МЕДИЦИНА И КОСМИЧЕСКАЯ ПСИХОЛОГИЯ В АСПЕКТЕ РАЗВИТИЯ «НАУК О ЧЕЛОВЕКЕ»

В. В. Терешкова[1], Е. А. Терешкова[2], Д. Е. Фирсов[3] ✉

[1] Государственная Дума Федерального собрания Российской Федерации, Москва, Россия

[2] Благотворительный фонд Терешковой, Москва, Россия

[3] Институт психологии, социологии и биоэтики, Ярославский государственный медицинский университет, Ярославль, Россия

Риски, связанные с полетами человека в космос, являются одним из ключевых факторов определения перспектив космических программ. К многочисленным формам негативного воздействия космической среды на организм человека относятся космическая радиация, невесомость, потеря мышечной массы и ухудшение слуха. Дополнительные вопросы возникают в связи с неизбежным расширением взаимодействия техники и человека там, где присутствие исследователя на данный момент трудноосуществимо. В связи с этим определяющее значение для развития космических проектов имеет прогресс биологии, медицины и психологии, изучающих адаптивные возможности человека не только в физиологическом аспекте, но и в ракурсе духовности. Потенциал космической биологии, космической медицины и космической психологии как «наук о человеке» задает перспективы научных исследований и практических решений по освоению ближнего и дальнего космоса на основе обширных данных не только о физиологических и психологических возможностях человека, но и о его духовных ресурсах, в совокупности определяющих способность к адаптации в новой физической и культурной реальности.

Ключевые слова: космическая биология, космическая медицина, космическая психология, «науки о человеке», духовные ресурсы

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✉ **Для корреспонденции:** Денис Евгеньевич Фирсов
ул. Революционная, д. 5, г. Ярославль, 150000, Россия; f300670@mail.ru

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Due to rapid advancements in science and technology, solving the ethical dilemmas of 21st-century space exploration is a necessary civilizational task. UNESCO's decision to expand the powers of the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) [1] allowed to adopt Concept Note on Ethical Considerations on Space Exploration and Exploitation [2] as part of the work program for 2024–2025. The note addressed the risks of spaceflight, including numerous negative effects of the space environment on the human body, such as cosmic radiation, weightlessness, loss of muscle mass and hearing impairment.

In this regard, advancements in space biology, space medicine, and space psychology significantly contribute to the success of space projects. The sciences do not only experimentally determine human adaptive capabilities. Biology, medicine, and psychology function as "human sciences" in a broad sense, exploring both physiological and spiritual resources of a human.

In the work entitled "Space medicine and biology: today and tomorrow" by Ushakov IB it was noted that "biological experiments in space in the next decade should be aimed primarily at solving biomedical problems related to future human flights into deep space" [3].

Ushakov IB believes that the priority problems of space biology are as follows:

- cellular and molecular mechanisms of adaptation to weightlessness and readaptation to terrestrial gravity;

- dependence of structural and functional changes in the body on duration of stay in zero gravity, age and gender;
- possible damage to the body due to the combined effects of weightlessness and high radiation from space;
- biological effects of artificial gravity and prolonged exposure to simulated hypogravity (1/6 and 1/3 g) using on-board centrifuges;
- effectiveness of new physical and chemical (pharmacological) means of preventing the adverse effects of weightlessness and cosmic radiation;
- survival and viability of terrestrial organisms under prolonged exposure to open space;
- technologies for higher plants cultivation in zero gravity [3].

The first Russian biological research was conducted while studying the stratosphere and as part of early aerospace developments. In the second half of the 1940s, the need to study the problem of human flight on rocket aircraft was justified, initiating collection of information on the impact of adverse flight factors in animal experiments. Over 50 dogs used in flights on geophysical rockets, artificial Earth satellites and spacecraft to an altitude of 100–450 km were examined at the Institute of Aviation Medicine and the Institute of Biomedical Problems [4].

It was on November 3, 1957, when Russian researchers first recorded vital signs from Laika, the dog, transmitted from the artificial Earth satellite. In 1960–1961, the means for safe return of animals to Earth were developed, and physiological reactions of the animal in prolonged weightlessness were recorded. Flights of Belka and Strelka in August 1960 and some space experiments with animals and biological objects made it possible to assess human stay in orbit and safe return to Earth [4]. The use of animals in experimental research is crucial for advancing human spaceflight.

Significant scientific data have been currently accumulated from a broad range of experiments and studies on mammals (mice, rats, monkeys) and higher plants in Earth-based and space-based conditions on spacecraft such as the Salyut, Mir, International Space Stations, and the Bion series of biosatellites. The research explored the effect of weightlessness on the physiological systems of animals, in particular. The results show that weightlessness mostly affects the muscular, skeletal, sensorineural, and cardiovascular systems. The numerous structural and functional changes observed are generally non-pathological, but adaptive responses; they get back to normal shortly after the end of the flight. Experiments on rats have shown that artificial gravity created by the rotation of animals during flight in an on-board centrifuge can support normal functioning of many body systems in weightlessness under terrestrial conditions [3].

Advancement of space biology significantly influences the progress of space medicine. Just like it was with space biology, fundamental and applied research in space medicine are closely interrelated as well, including those aimed at obtaining new data on how space and space factors influence living systems and solving medical safety problems in manned space missions. Thus, space medicine “is an important practical element of manned cosmonautics, which largely determines the state and prospects of outer space exploration by humans” [3].

Russian space medicine went through several stages of development [4]. It was preceded by research of aviation physiology at the Department of Aviation Medicine of the Central Institute for Advanced Medical Training (since 1939) and at the Faculty for Training of Aviation Doctors of the 2nd Moscow Medical Institute (since 1940) of the Scientific Research Testing Institute of Aviation Medicine (since 1949) using unique stands and simulators.

In 1961–1965, Vostok-1, Vostok-6, Voskhod, and Voskhod-2 spacecrafts were used to explore human capabilities in weightlessness for up to 5 days, specifics of space flight for female cosmonauts, and reliability of a spacesuit to ensure human operation in outer space.

At that time, research was conducted by Energia NPO, the Space Administration, established at the Institute of Aviation Medicine, the Cosmonaut Training Center, and the Institute of Biomedical Problems of the Ministry of Health of the USSR. The first 20 cosmonauts were selected and trained to develop professionally significant psychological qualities. Yuri Gagarin’s 108-minute flight started a new stage of space and space medicine exploration:

- the first flight of Nikolayev AG into space on the Vostok-3 spacecraft on August 11, 1962, that lasted 4 days, when the cosmonaut detached himself from the chair for the first time and controlled the spacecraft independently, the first group flight,
- a flight of Tereshkova VV on the Vostok-6 spaceship on June 16, 1963, who was the first female cosmonaut to pilot a spaceship alone,
- flight of Komarova VM, Feoktistova KP and Egorova BB in October 1964,
- Belyaeva PI and Leonova AA on the Voskhod-2 spaceship in March 1965, and walking of Leonov AA in open space were possible due to the collaboration of space medicine specialists.

The second period was associated with further advancement of space physiology and medicine in 1967–1970 due to long-duration missions using Soyuz spacecraft, in prolonged weightlessness and external environment, and spacecraft docking (1969). The Soyuz 9 mission with Andrian Nikolayev and Vitaly Sevastyanov, which took place in 1970, was the first longest flight in space. It lasted 18 days. During the flight, crew members lost about 30% of muscle mass. It was called “the effect of Nikolayev”. The third period started in 1971 with long spaceflights on the Salyut, Mir and MCS spaceships, which are currently used as orbital research stations. Medical researchers Atkov OYu and Polyakov VV were members of the crew on bord the stations.

Domestic and international experimental projects allowed to explore the impact of long-term weightlessness on cardiovascular and respiratory systems, metabolism, digestion and absorption, motor, ocular, vestibular apparatus, immune system, bone tissue, and to improve the basis of nutrition and water provision [4].

Research in space psychology is closely related to space biology and space medicine [5]. At the first stages of space program development, space psychology dealt with selection of first cosmonauts, risk of long-term crew isolation, and design of space vehicles. Academician of the Russian Academy of Education Ponomarenko VA made a significant contribution into development of the Russian school of space psychology.

Space psychology aims at prevention of risks associated with the influence of physical and physiological factors such as weightlessness, sensory deprivation overload, changes in time perception, and socio-psychological features of interaction among crew members in an isolated small group. Psychological reliability, reasons for human errors, human activity during spaceflight with high emotional load, high responsibility and mental activity, impact on perception, thinking and memory are analyzed. Development of methods of special training of cosmonauts to prepare for overload and other factors allowed to substantiate psychophysiological recommendations to enhance control over all flight values including the ones with automation of many operations and associated risks of engineering and mental equipment defects.

Ponomarenko VA states that spirituality of a space explorer plays a crucial role in enhancing their effectiveness during harsh flight conditions. Understanding the meaning of activity while revealing spiritual mastership improves traditional abilities and effectiveness of human actions in space due to potential self-development and self-improvement [5].

In the context of technological progress, modern space psychology successfully addresses training cosmonauts for difficult professional conditions [5].

The high degree of prolonged exposure to cosmic radiation during space flights and on the surface of planets (low Earth orbit, Moon, Mars, asteroids, etc.) raises questions about development of technologies to minimize the risks. Nevertheless, current space exploration relies heavily on robotic systems.

Thus, taking into account the inevitably growing interaction between technology and humans, ethical issues of introducing artificial intelligence and other digital technologies into research practice are becoming particularly relevant, including the widespread use of neurotechnologies in human-machine interaction in the future.

At the 41st session of the UNESCO General Conference, which took place from November 9 to 24, 2021, 193 countries adopted a Recommendation on the Ethics of Artificial Intelligence [6]. Without directly addressing the issues of AI application in space exploration practice, the Recommendations contain a number of provisions that correspond to the goals and objectives of space research.

In particular, it is stated in the Recommendations “that taking into account risks and ethical aspects should not hinder innovation and development; on the contrary, new potential opportunities should be provided, and that it is necessary to stimulate ethical research and innovation activities that promote a linkage between AI technologies, human rights and fundamental freedoms, moral values and principles.” … “moral principles and values can contribute to the development and implementation of policies and standards of a human rights nature and act as guidelines, taking into account the high pace of technological development.”

“5. The purpose of this Recommendation is to lay the foundations for using AI for the benefit of all mankind, individuals, societies, environment and ecosystems and to avoid harming them. Its goal is also to encourage the use of AI-based systems for peaceful purposes.”

“17. At all stages of the AI system life cycle, it is essential to accept the important role of the environment and ecosystems, protect them and promote their well-being. Moreover, a healthy environment and healthy ecosystems are vital for survival of humanity and other living beings, as well as for enjoying the benefits of AI advancement.”

“25. It should be understood that AI-based technologies do not guarantee well-being of humans, environment and ecosystems … appropriate risk assessment procedures should be used, and certain measures should be taken to eliminate the likelihood of such harm”.

“50. Member States should establish a legal framework that sets out a procedure for impact assessments, and ethical impact assessments, in particular, in order to identify and analyze the benefits, challenges and risks associated with the use of AI-based systems, as well as to take appropriate measures to prevent, minimize and monitor such risks and establish other guarantee-based mechanisms”.

A number of issues that may relate to AI applications in space research are discussed in the Preliminary Draft UNESCO Recommendations on Ethics of Neurotechnology published in February 2024 [7].

“91. Member States should jointly develop clear and unified guidelines on IP rights for neurotechnology on an international scale. These guidelines should take into account patentability of AI-created inventions and ethical implications of IP laws, as well as foster global access and innovation.” Taking into account the scope of medical research related to human participation in space research, it is important to “82 … develop a reliable regulatory framework governing collection, processing, exchange and all other uses of neural and cognitive biometric data. Such a regulatory framework and existing regulations should recognize that this data is personal and confidential in both a medical and non-medical context”.

The level of responsibility and long-term planning in conducting research in artificial intelligence and neurotechnology within the space industry undoubtedly corresponds to the “research integrity” introduced by the UNESCO draft text of the Recommendation on the Ethics of Neurotechnology.

“38. Research integrity is a commitment to a rigorous search for truth through scientifically sound, objective, and transparent research methods. It ensures that all scientific research in neurotechnology-related disciplines is based on the principles of honesty, accuracy and respect for the scientific method.”

Ethical aspects of using AI technologies and neurotechnologies in space research are further discussed by specialists in technical and humanitarian knowledge. This discussion is crucial for the prospects of studying the possibilities of a human activity in the Universe.

CONCLUSIONS

According to Professor Ushakov IB, Academician of the Russian Academy of Sciences, Dr. Med. Habil., a Russian specialist in extreme environmental physiology, “space medicine and biology have a fascinating future, which is primarily based on an unconditional need in their development to ensure further space exploration by a human, including far space… Space medicine of the future will continue staying ahead… It has always been and will continue to be medicine of combined effects and personalized (individualized) biomedicine, not only according to the human genome, but also according to its phenotype. Space biology research results are crucial for advancing space medicine” [3]. Development of space biology, space medicine and space psychology as “human sciences” determines the level of objective planning of scientific research prospects and practical tasks for the exploration of near and far space, taking into account the physiological, psychological and spiritual resources of humans and their ability to adapt to a new physical and cultural reality.

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