

Opportunities for transfer of knowledge in space biology and medicine

Oleg I. Orlov, Tatiana N. Agaptseva*, Mark S. Belakovskiy, Anna R. Kussmaul

^a *Institute of Biomedical Problems of the Russian Academy of Sciences (IBMP RAS), 76A Khoroshevskoye shosse, Moscow, Russia 123007, info@imbp.ru*

* Corresponding Author

Abstract

The projects and initiatives for sharing experience and knowledge of the specialists play an important role in the development of space industry and sciences all over the world. The Institute of Biomedical Problems was founded 60 years ago, in the earliest days of manned cosmonautics, and it secured a leading position in the field of space biomedicine for more than 50 years. The Institute is ready to share its knowledge and experience with foreign colleagues interested in space activities and has developed a system providing an integrated approach and full immersion in this field of science. The system includes consulting services in the field of space biomedicine and preparing abstract reviews in various areas of research; giving seminars and workshops on space biology and medicine; joint programs for training specialists in space biomedicine; lectures for students and postgraduates; educational and exhibition programs for children, youth and the general public, as well as conducting ground-based analog research using experimental facilities. This system allows to share effectively the unique experience of the IBMP in the field of space medicine and biology.

Keywords: knowledge transfer, space biology and medicine, unique scientific facilities, world-class research center

Acronyms/Abbreviations

ANOG – antiorthostatic hypokinesia
SAC – Short-Arm Centrifuge
ESA – European Space Agency
IBMP – Institute of Biomedical Problems
ISS – International Space Station
JSUP – Japan Space Utilization Promotion Center
KAERI – Korea Atomic Energy Research Institute
MBRSC – Mohammed Bin Rashid Space Centre
MEDES – French Institute for Space Medicine and Physiology, in French ‘Institut de Médecine et de Physiologie Spatiales’
NASDA – National Space Development Agency of Japan
NEK – Ground-Based Experimental Facility, in Russian “Nazemniy Experimentalniy Komplex”
NSBRI – National Space Biomedical Research Institute
WCRC – World-Class Research Center

1. Introduction

It is obvious that the deep-space exploration requires combining the experience and knowledge of the specialists from all over the world. From the other side more and more countries and organizations enter the space industry and are interested in the transfer of knowledge in this field. [1]. That is why the projects and initiatives for sharing such experience play an important role in the development of space industry and sciences. [2,3]

2. The 60-year experience in the field of space biology and medicine

The Institute of Biomedical Problems (IBMP) was founded 60 years ago, in the earliest days of manned cosmonautics. Its main objective was to create a comprehensive biomedical support system for piloted space missions of various duration. The objective was accomplished successfully, and the IBMP secured a leading position in the field of space biomedicine for more than 50 years.

Much has changed since the first flight into space performed by Yu.A. Gagarin. The technological progress advanced, and the first Vostok and Voskhod spacecraft were replaced by Soyuz launchers, the Salyut and Mir orbital space stations and the International Space Station (ISS), and now manned deep space exploration is underway, together with the launch of Lunar orbital stations, Martian expeditions and the construction of planetary bases. Each

new step in piloted cosmonautics was preceded by in-depth studies of methods to ensure safety, health and performance of cosmonauts and astronauts, carried out by IBMP and other scientific organizations.

Over the past 60 years, the IBMP has preserved its focus on studying the living conditions and working capacity under the influence of extreme factors, tracking changes occurring in the bodies of living beings at various levels and countering adverse impact of environmental factors not only in space flight, but also during deep-sea diving, Arctic expeditions and other extreme conditions.

Throughout the years, the IBMP scientists have accumulated a wealth of knowledge in the field of space biomedicine and extreme medicine, continuously conducting research both in ground-based analog conditions and real space flights. This knowledge has always been in demand both with leading space agencies - our long standing partners -, and with newcomers to the space sector, the number of which is growing every year.

3. The IBMP system for knowledge transfer

The Institute is ready to share its knowledge and experience with foreign colleagues interested in space activities. For this purpose, a system that provides an integrated approach and full immersion in this field of science has been developed. The system includes:

3.1 Consulting services in the field of space biomedicine and preparing abstract reviews in various areas of research

For many years, the IBMP specialists have been preparing reviews for our scientific partners. Those cover various topics of space medicine and biology, including the influence of space flight factors on human body systems, the problems of microbiological and radiation safety in space missions of various duration, psychological support etc. In particular, we prepared reviews on: the problems of human adaptation in space (for French Institute for Space Medicine and Physiology (MEDES) and European Space Agency (ESA)); radiation safety in piloted space missions and radiation control on board manned aircraft (for Toyo Engineering and National Space Development Agency (NASDA), Japan); psychological problems of long-term space flights (for Japan Space Utilization Promotion Center); microbial contamination on board manned spacecraft (for ESA) and others.

3.2 Giving seminars and workshops on space biology and medicine

IBMP scientists conduct travel scientific seminars on various topics, which allow a wider audience like foreign students and postgraduates to gain knowledge in the field of space biology and medicine. Thus, scientific seminars were held at National Space Biomedical Research Institute, NSBRI (USA) ("Results of studying the influence of space flight factors on human physiological systems and psychological status"), Korea Atomic Energy Research Institute, KAERI (South Korea) ("Results of studying the influence of space flight factors on biological systems") and other countries and organizations.



Fig. 1. The workshop in ESA dedicated to the results of MARS-500 project

3.3 Joint programs for training specialists in space biomedicine

It is possible to either adapt the already existent training programs to the tasks and specifics of ongoing research or educational programs, or to develop new ones specifically at the request of interested organizations.

A successful example of such adaptation is the "Space biology and medicine" course, developed for students pursuing degrees in General Medicine. The course includes the following topics: adaptation of the body to gravity;

biological effects and modeling of microgravity; the impact of space flight on human physiological systems; sensory systems and spatial orientation; symptoms, pathogenesis and countermeasures to motion sickness; the hypogravity syndrome; lack of support load and bone system; hematopoietic systems and immune system in space flight; mutagenicity of space flight factors and others.



Fig. 2. The certificates for the foreign specialists passed the training on the Russian system of medical support for the human space flights

3.4 Lectures for students and postgraduates

The IBMP experts have prepared a series of lectures including more than 60 topics on history and current status of space biology and medicine. The main courses of lectures cover the following areas:

- Space biology, including the results of animal studies in biosatellite programs, space cell biology, microbiology, the influence of space flight factors on the reproductive system of animals, the growth and development of lower autotrophs, etc.,
- Gravitational physiology, including the study of cardiovascular, respiratory, muscular, bone and other systems of the human and animal bodies in the conditions of weightlessness and extreme environmental factors;
- Space medicine, including astronaut selection and training, countermeasures to negative space flight factors, medical support for space flights, sanitary-hygienic and microbiological control, etc.

An important direction here is the involvement of students in activities related to space biology and medicine. At the IBMP, university students have an opportunity to prepare term papers and theses. In addition, the Institute is the only state institution where postgraduate students can study and present their theses for the degree of "Candidate of Sciences" (a Russian analog of the PhD degree) in the field of aviation, space and marine medicine.

The list of topics for lectures and reviews can be extended in accordance with the requests of organizations and countries interested in training relevant specialists.

3.5 Educational and exhibition programs for children, youth and the general public

Obviously, promoting the achievements of space biology and medicine can have a significant effect in shaping the self-consciousness of society, especially young people. Such a knowledge-intensive industry can not grow without a constant flow of young highly professional and motivated personnel. This is why the IBMP pays great attention to working with children and youth, which includes:

- development and implementation of educational experiments on board the ISS and biological satellites, including active participation of schoolchildren (for example, the Herminis experiment, that studied the influence of space flight factors on the vital activity of plants with a radical change in the gravitational environment during germination, developed by Moscow schoolchildren under the guidance of an Institute staff member);
- providing tours around the Institute, where schoolchildren and students get acquainted with the activities of the Institute's laboratories and the history of modern space medicine, see our traveling exhibition and memorial museum rooms;
- lectures for schoolchildren at various venues: in schools, youth creativity centers, specialized aerospace classes, scientific youth festivals and conferences;
- competitions of research and abstract works of students.

For example, the Experiment in Space project gave birth to a system which provides students with competitive access to participate in real space programs using the International Space Station, transport ships and satellites.



Fig. 3. The Japanese schoolchildren participating in MicroLADA project.

4. Joint work at the Unique Scientific Facilities

In addition to scientific knowledge transfer, the Institute is ready to share its unique practical experience in conducting ground-based analog research using the experimental facilities. The scientific problems solved by the IBMP specialists contributed to the creation of new stands, instruments and scientific equipment to support research in laboratory, semi-natural and full-scale conditions. This led to the creation of the Unique Scientific Facilities, which include:

- The Ground-Based Experimental Facility (or the NEK), created in 1964-1970 to conduct scientific experiments with human participation in an artificially regulated habitat. The facility has been redesigned and modernized many times, and now it is used for most realistic simulation of interplanetary flights, including to the Moon and Mars. The NEK is equipped with communication with the mission control center, a permanent video surveillance system, modern life support systems and a simulator of the surface of an alien planet. There are no complete analogues of this facility in the world.



Fig. 4. The specialists from the Chinese Astronaut Training Center and Mohammed Bin Rashid Space Centre get acquainted with the NEK systems` work

- The Short-Arm Centrifuge (SAC), which is a multifunctional unique new-generation stand developed to solve the problem of creating artificial gravity on board a spacecraft. It has a number of advantages compared to similar installations, for example, it provides an opportunity to install additional technical and medical equipment and use physical training machines. The SAC's unique technical characteristics make it possible to solve a wide range of space medicine problems, carry out all the necessary ground research and training, as well as to improve the methods of treatment and rehabilitation of patients with disorders of the musculoskeletal system and cardiovascular system.

- The Dry Immersion stand, created in the 1970s, is a unique model for ground-based reproduction of the physiological effects of short-term space flights. The stand consists of an ergonomically designed immersion bath of strictly calculated depth, with a built-in lifting mechanism and a highly elastic waterproof fabric attached to the outer edge of the bath, as well as a number of countermeasures to motor disorders usual for a space flight: a suspension stand for locomotor training in a horizontal position, an axial loading suit, a plantar simulator of support load, and a low-frequency electromyostimulator.

- The Hypogravitation stand, which allows to simulate the physiological effects of micro- and hypogravitation. The method of antiorthostatic hypokinesia (or ANOG), when the human body is inclined by -6° relative to the horizon, is used as a model of prolonged stay in zero gravity. The Hypogravitation stand allows for complex multi-day experimental studies with the simultaneous participation of up to 14 test subjects. Equipping the stand with modern technologies for neurophysiological research will create conditions for the standardization of methods for evaluating the effectiveness of the countermeasures used to prevent the negative effects of microgravity.

Taking part in the Institute's research provides an opportunity for specialists who are just starting their activities in piloted cosmonautics to see in practice how large-scale international analog projects are organized and implemented, how modern countermeasures systems work and how the acquired knowledge and skills can be applied.

5. Cooperation in the frame of World-Class Research Center “The Pavlov Center”

The World-Class Research Center (WCRC) - the Pavlov Center «Integrative Physiology to Medicine, High-Tech Healthcare and Technologies of Stress Resistance» can become a good platform for such cooperation and knowledge transfer. The WCRSs are consortia created within the framework of the Russian National Project "Science". The Project's goals included a competitive selection of candidates for grants from the federal budget for the creation and development of world-class research centers in priority areas of science and technology. The structure of the Pavlov Center WCRC includes several leading institutes in the leading areas of physiology and medicine, including IBMP. Each element of the consortium has its own role, thus, the Center for Study and Prevention of the Effects of Long-Term Isolation has been established at IBMP for the purpose of investigation of stress caused by prolonged physical and social isolation through model experiments, as well as the approaches to prevent such stress. These studies will allow to substantiate the methods of psychological support, as well as to propose new methods and modes of electromyostimulation and gravity therapy for clinical practice. The specialists of the Pavlov Center give lectures and conduct seminars on a whole range of topics, in addition, it is possible to organize internships at the Center for Study and Prevention of the Effects of Long-term Isolation.

6. Conclusions

Thus, the IBMP has a great potential in the field of knowledge transfer in space biomedicine and is ready share knowledge with interested organizations and specialists, both on separate topics and in a whole.

Acknowledgements

The manuscript is prepared with the support of the Ministry of Education and Science of Russia in the framework of agreement No. 075-15-2022-298 dated 18.04.2022 on the provision of a grant in the form of subsidies from the federal budget for the implementation of state support for the creation and development of the world-class scientific center - Pavlov Center “Integrative Physiology for Medicine, High-Tech Healthcare and Stress Resistance Technologies”.

References

- [1] ESPI Report 79 - Emerging Spacefaring Nations - Full Report, European Space Policy Institute (ESPI), ISSN: 2218-0931 (print) • 2076-6688 (online), June 2021
- [2] P.C. Yuen, Knowledge Transfer in Space Science, The 5th International Conference on Knowledge Management Asia Pacific, Xi'an, China, 2010, 16-18 September.
- [3] P. Kasatkin, A. Sumin, N. Shelyubskaya, International Knowledge Transfer, in book: World Economy and International Business, Springer Cham, 2023, pp.765-781. DOI:10.1007/978-3-031-20328-2_38