УДК 629.78

PROJECT OF THE SPACECRAFT MODULE FOR BIOLOGICAL EXPERIMENTS IN ARTIFICIAL GRAVITY

D. S. Velmozhin

In this work, the result is obtained - a draft design of the spacecraft module intended for conducting biological experiments with artificial gravity technology. The necessity of developing research in the field of artificial gravity technologies is substantiated. Theoretically, an interesting effect associated with the design features has been found. The author draws attention to the general concept of the project, the layout of nodes and aggregates. The author's task is not to make a complete design calculation. the author's task is to present a draft design: a 3D model that reflects the main idea of the project and its components. The author focuses on the use of modern computer technologies in the project, which were not available in previous experiments on this topic. This work is useful as a fresh look at the solution of an urgent problem that has accompanied manned space since its inception.

Ключевые слова: technology development, computer technologies, modern technologies in space engineering, application of artificial intelligence, influence of space conditions on health, 3D-model.

Currently, this problem is well studied, there is an intermediate solution that compensates for the impact of the lack of gravity onboard spaceships and meets the needs of the space industry at the moment, but in author's opinion, in the future development of manned space exploration will require a completely different approach based on the experience of previous years and focused on the application of modern technological solutions.

This article describes to a greater extent the author's project, however, we note that current research programs on this topic exist and periodically appear in the media about them.

«Specialists of the Institute of medical and biological problems (IMBP) RAS is testing a short-radius centrifuge to create artificial gravity on the International space station, Director of the Institute Oleg Orlov told RIA Novosti» [1]. The ISS module that Orlov is talking about is similar to the author's project, but the author's project has a broader purpose.

In this article, the author calls the comic devices of the «Bion» series a potential platform for the designed module. Referring to the TASS report: «Equipment for creating artificial gravity can be installed on the Russian scientific satellite «Bion-M» number 3, which should go into orbit in 2025. This was reported to journalists by Vladimir Sychev, Deputy Director of the Institute of medical and biological problems of the Russian Academy of Sciences» [2] indeed, Bion can be considered as a carrier spacecraft for the module.

When working with existing devices, it is important to know their technical characteristics, which also dictate the requirements for scientific equipment. The characteristics of the device described above are presented on the website of RSC Progress [3] – the manufacturer of these devices. The module described in this article corresponds to them.

The conditions and research methods

Research in this work has been carried out in theoretical field, which made the process of creating a project more flexible, and the development does not depend on the material component. It is important to note that theoretical research is inevitably accompanied by its disadvantages, in particular, application of the results of such research in practice can be difficult.

The main method of this research is modeling in several of its manifestations: theoretical

Velmozhin Daniil Sergeevich (mr.velmozhin@mail.ru), student I course of the Institute of Space Rocket Engineering of the Samara University, 443086, Russia, Samara, Moskovskoye Shosse, 34.

modeling environment in which the spacecraft module is to work (hereinafter SCM), the creation of a computer model of result - sketch of three-dimensional visualization and theoretical modeling research experiments developed by the SCM.

The second most important method on which the research is based is the analysis of information at all stages of the research. Thus, the sources of data for analysis in this work are: data on the current situation and development of the space industry, current technological trends, both in the field of rocket and space technology, and in related industries, in particular in the field of artificial intelligence technologies; the results of previous research on this topic, as well as interim conclusions and hypotheses obtained in the course of this work.

The use of the methods described above is aimed at creating a result that has new properties that favorably distinguish it from other similar projects.

Problems of the task

Currently, there is a trend to develop spaceships that can take a person to the Moon and Mars. Specialists of leading companies in the industry are purposefully engaged in the creation of interplanetary spaceships. Special attention is paid to the design of life support systems for a crew and systems for protecting the human body from the negative impact of space factors.

One of interesting tasks is to research the effect of artificial gravity on living organisms over a long period of time. At the moment, this is one of the main problems of manned cosmonautics, because in the absence of gravity, biological processes of living organisms are disrupted and at the moment this leads to the fact that a person can’t be in space for a long period of time, about several years, especially since we are not talking about creating a colony of humanity in space with a change of generations.

In this research paper, attention is paid to the analysis of the possibility of creating a small-size SCM for conducting biological experiments in conditions of artificial gravity.

Potential research objects in experiments

Presumably, small rodents and geckos are suitable as research objects. This choice was not made by chance.

Laboratory mice and rats are the subject of a large number of researches on Earth, so there is a large database of these animals. Data obtained as a result of experiments in the SCM can be quickly compared with data from similar studies in Earth conditions, which, in turn, allows you to adjust the research program to obtain the best results.

Geckos have a specific structure of limbs that allows them to attach to a surface; potentially this is one of the factors due to which the lack of gravity has less effect on them. In turn, they have an important advantage, they are unpretentious and consume a small amount of food and water, which means that they can be used for long-term research, including experiments on animal reproduction outside the Earth.

Potential spacecraft for this module

This question concerns the more practical part of the project implementation, but in the framework of theoretical development, it is important to note that the proposed spacecraft (SC) can be adapted to work with the SCM and the requirements that are imposed on them.

First of all, the SC is to provide the SCM systems with electricity and a two-way communication channel with the ground control center. Power consumption of the module is expected to be such that the SCM can be considered as a payload for interplanetary missions whose main equipment is inactive during the flight to the target celestial body, Mars as an example. When the main equipment is switched on, the SCM is switched to a more economical mode of energy consumption, with the exclusion of some data collection systems that consume the most resources, the active research phase can be resumed during the SC's return flight to Earth. Now we let us proceed to the consideration of options AS-carriers.

First of all, we should mention that the International space station (ISS) is one of the main tools in the exploration of space by mankind. The advantages of the ISS include possibility of operational intervention in the operation of the SCM for maintenance or repair using robotic systems or with the help of astronauts in outer space, because the SCM will be located outside the station. In such conditions, the term of research is limited only by the service life of the SCM construction.

In addition to the ISS for missions in near-earth space SC series "BION" suit, in this case, we consider the return of objects of study to the Earth, but it complicates and aggravates the design of the ICA, the service life in such conditions is limited by supplies of water, food and oxygen.

An example of a SC for interplanetary research is the «FOBOS-GRUNT». Research in deep space is the most difficult issue, since the ability to return research objects to the Earth requires the use of heavier launch vehicles. According to the author, it is possible to achieve high quality and volume of data as a result of remote research, then the research period can be longer, but it will be a one-way flight.

Overview of the module design

It is based on the classic toroidal shape, which was subjected to significant modifications, which mostly addressed the elimination of shortcomings. Thus, the toroidal outer habitable block (OHB) is divided into three movable sections equipped with folding mechanisms. This solution solves the following problems.

1) Reducing the number of auxiliary structures at the stage of launch. The arrangement of the sections one above the other and the transfer of the load by the design of the SCM allows you to use reinforced support for one section and lightweight support in the space between the sections. The circle in the section makes the construction of sections highly susceptible to loads, reducing the risk of damage to the weak link-the connections of the external and central blocks.

2) Compact. Folding sections according to the author's calculations potentially reduces the required amount of space under the head fairing by 30% compared to the space required for placing a module with a fixed shape.

It is important to note that this decision necessitated the installation of dampers at the junctions of sections and the installation of detachable electrical connections and air pipes.

In the OHB, most of the space is occupied by a habitable space, similar in cross-section to the cabin of an airliner, the cut - off parts of the circumference of the section are used for air ducts for supplying clean air and removing dirty air and solid particles. As well as laying electrical wiring and placing large sensors, like a video camera. Approximately 1/6 of the OHB is occupied by a removable container (RC) and its site. In the RC, a little more than half of the volume is occupied by an isolated volume, in which the objects of research are at the launch stage. The second largest component of the RC is a food container with a screw feeder that serves animal feed in portions. Next in order of decreasing size is the unit for collecting solid particles and treating the air with ultraviolet light, followed by a system for separating the mixture of water and gases supplied from the central unit, and updating the air composition by replacing part of it with a mixture of nitrogen and oxygen.

Alternatively, possibility of placing a carbon dioxide regenerator in the central unit to saturate the air with oxygen was considered. These improvements allowed us to achieve the following results:

High density layout. SCM is small in size, the draft is the diameter of the torus at the center of 1 m, cut-off diameter 0.3 m, the maximum diameter SCM 1.3 m. There is almost no empty space between the blocks, the length of the connecting beams is no more than 0.2 m, and the diameter of the Central block is 0.3 m.

Onboard computer and artificial intelligence

The high autonomy of the ICA achieved through the use of artificial intelligence in the onboard computer, allows you to transmit less data to and from the Earth, since control commands from the Earth are only needed in certain situations, data traffic from the sensors goes from the module to the Earth in «raw» form or «compressed» after processing by artificial intelligence.

According to the author's idea, the most important parameters of the SCM state (air temperature and composition, noise, vibration and radiation pollution, artificially created acceleration) and objects of research (animal behavior, their body temperature, the ratio of periods of activity and rest, biological rhythms) are monitored by artificial intelligence (AI) through a network of sensors. In addition to the observation function, AI also has a control function-the ability to set the parameters of the module described above and others that affect the objects of research (day/night cycle, feeding, including scientific equipment for various tests). Such work requires the AI to know the normal behavior of animals on Earth, so they are it to be trained beforehand in terrestrial conditions.

With this concept, the lion's share of the work of scientists, AI takes over, sending to the Earth only the results developed as a result of the work of its algorithms. Two types of results are expected. The first type includes the results of experiments to bring the conditions of life in the module to the Earth. The second type is to determine the optimal conditions for the life of an SCM, probably different from Earth's.

Expected interesting effects of SCM influence on the inhabitants

While working on the project, the impact of the SCM design on its inhabitants has been studied. As a result of this part of the study, the following effects have been found, described by the science before.

Coriolis effect

This effect in the scientific literature is called the main disadvantage of centrifugal systems for providing artificial gravity, which includes our system.

Since an animal or a person has a certain size, the distance from different parts of the body to the axis of rotation is different, and therefore the perceived acceleration is also different. This affects the vestibular apparatus, which leads to a deterioration of the condition of the living organism. It is believed that it is possible to compensate for the effect by training. In our case, during experiments in the ICA, it is possible to test the adaptation of living organisms in ideal conditions. Experiments with centrifuges on the Earth still do not exclude the influence of the Earth's gravity, so there are distortions in the perception of this effect.

«Mountain» effect

In the conditions of SCM, there are mainly two types of movement "in the direction of rotation" and "against the direction of movement". In the first case, the faster the animal moves, the greater its angular velocity relative to the axis of rotation, which consists of the angular speed of rotation of the OHB and the speed of movement of the animal relative to it with some transformations. In this way, there is an increase in acceleration, which is felt as a difficult movement, comparable to movement in an elevator up or up a mountain.

In another case, the angular speed of the animal relative to the axis of rotation is less, since the angular speed of rotation of the OHB is subtracted from the speed of movement of the animal in it. Therefore, the acceleration felt by the animal decreases. This is comparable to the feeling of moving in an elevator down or down a mountain.

Conclusions

This paper theoretically describes the concept of a spacecraft module for conducting biological experiments with artificial gravity technology, justifies the need for research in this direction. The concept includes a preliminary design of the SCM with indication of its main parts, the technologies used, as well as the purpose of the designed module and possible problems that can be solved by such experiments.

Acknowledgement

The author is grateful to scientific supervisor's: **Volotsuev V. V.**, associate Professor of space engineering General designer D. I. Kozlov; **Salmanova O. D.** senior lecturer of the department of Foreign Languages and Russian as a foreign language and student Design Bureau "RocketLAV" Samara National Research University for assistance and expertise in the process of creating the work!

References

1. RIA Novosti. Media. URL: https://ria.ru/20190319/1551922033.html (accessed 28.05.2020).

2. TASS. MEDIA. URL: https://tass.ru/kosmos/3476791 (accessed 28.05.2020).

3. RSC «Progress» official website URL: https://www.samspace.ru/products/satellites_of_scientific_purpose/ka_bion_m_1/ (accessed 28.05.2020).

ПРОЕКТ МОДУЛЯ КОСМИЧЕСКОГО АППАРАТА ДЛЯ ПРОВЕДЕНИЯ БИОЛОГИЧЕСКИХ ЭКСПЕРИМЕНТОВ В УСЛОВИЯХ ИСКУССТВЕННОЙ ГРАВИТАЦИИ

Д. С. Вельможин

В данной работе получен результат - эскизный проект модуля космического аппарата, предназначенного для проведения биологических экспериментов с технологией искусственной гравитации, обоснована необходимость развития исследований в области технологий искусственной гравитации, теоретически обнаружен интересный эффект, связанный с особенностями конструкции. Автор обращает внимание на общую концепцию проекта, компоновку узлов и агрегатов. Своей задачей автор не ставит полный расчет конструкции, задача автора – представить эскизный проект: 3Д-модель, отражающую основную идею проекта и его составных частей. Автор делает акцент на применении в проекте современных компьютерных технологий, которыми не обладали предшествующие эксперименты по данной теме. Данная работа может быть полезна, как свежий взгляд на решение актуальной проблемы, сопровождающей пилотируемую космонавтику со времен ее зарождения.

Key words: развитие технологий, компьютерные технологии, современные технологии в космическом машиностроении, применение искусственного интеллекта, влияние условий космоса на здоровье, 3Д-модель.

Статья поступила в редакцию 08.07.2020 г.

Вельможин Даниил Сергеевич (mr.velmozhin@mail.ru), студент I курса Института ракетно-космической техники Самарского университета, 443086, Россия, г. Самара, Московское шоссе, 34.