

BEFORE THE LONG JOURNEY

O. Gazenko

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16. Abstract One of the leading Soviet specialists in space biology and medicine gives a brief history of them. Now that the main questions of man's survival in space have been answered, we can move on to a deeper study of biological, biophysical and biochemical processes. This is necessary for long space trips. The application of space medicine discoveries to terrestrial medicine is discussed.			
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Space biology and medicine are three times younger than the Revolution. It, like cosmonautics in general, can emerge only when the scientific and economic potential of the country reach worldwide heights.

One of the leading specialists in space biology and medicine is academician Oleg Georgiyevich Gazenko. In 1956, he was included in a group of scholars entrusted with medical supervision of future space flights. Oleg Georgiyevich has directed the Institute of Medical Biological Problems of the Ministry of Public Health USSR since 1969.

In conversation with our correspondent V. Tyurin, O. Gazenko discusses the development of space biology and medicine and the problems which its specialists solve.

O. Gazenko
Academician

Sometimes they ask: what did space biology and medicine begin with? And in response sometimes one can hear or read that it began not with fear, but with questions such as: can man breathe, sleep, etc., in a weightless state?

Of course, these questions arose. But all the same, it is different from the era of great geographical discoveries when sailors and travelers followed routes without the least concept of what to expect. Basically we know what man should expect in space and this knowledge is fairly well founded.

*Numbers in the margin indicate the pagination in the foreign text.

I. Beginning in 1973, the scientists of our country have conducted biological experiments on Soviet sputniks of the Kosmos type (605, 690, 782, 936). These studies were conducted in co-operation with scientists of Czechoslovakia, the USA, and France. Scientists from Hungary, Poland, Romania have participated in them.

II. The first of the biosputniks, Kosmos-936, was equipped with a centrifuge which created an artificial force of gravity.

III. The animal life support system used on the biosputniks included: 1 -- an automated system for regenerating the atmosphere, 2 -- a magnetomechanical onboard analyzer for oxygen content, 3 -- an onboard analyzer for carbon dioxide, 4 -- high-precision small-dimension moisture content measuring device, 5 -- an automated system for collecting and removing animal waste, 6 -- air conditioning system; 7 -- an absorbing apparatus for harmful gaseous impurities.

IV. In vegetation there are cellular receptors for the force of gravity. Therefore, on Earth, independent of the position of the seed in the soil, the vegetation grows roots in the earth and stalks vertically in the atmosphere. The role of the force of gravity "sensors" in the cells is played by starch granules -- amyloplasts. Drawing number 2 [not included for translation] shows the caps of primary rootlets. On Earth, the amyloplasts, under the effect of gravitational force, are in the lower part of the cells, but in a weightless condition, they are distributed uniformly throughout the cell and cannot determine the direction of growth.

V. Experiments with low (1) and high (2) fungi. On Earth, they grow upward and in a weightless condition the lowest grow perpendicular to the substrata which plays the role of the soil independent of its position and the higher forms of fungi acquire an

incorrect shape.

V1. In this mobile laboratory, the studies of animals and vegetation which have existed in space are carried out immediately after the biosputnik lands using the following equipment: 1 -- a motor vehicle, 2 -- a tent for the study, 3 -- a tent for disassembly operations, 4 -- a heater, 5 -- a heating-ventilating unit, 6 - a gasoline unit, 7 -- control panel, 8 -- a container for the experimental objects, 9 -- an energy supply panel, 10 -- a biological box, 11 -- an operation table, 12 -- a table for the study, 13 -- a loudspeaker.

Space biology and medicine did not begin in a vacuum. It developed from general biology, was absorbed in the experience of ecology, climatology and other disciplines including the technological. A theoretical analysis which preceded the flight of Yuri Gagarin was based on the data of aviation, maritime and submarine medicine. Experimental data existed. Even in 1934, at first in the Soviet Union and even earlier in the USA, attempts were made to study the effects of upper layers of the atmosphere on living organisms, in particular, on the mechanism of fruit fly heredity. 1949 was the year of the first flights of animals -- mice, rabbits, dogs, in geophysical rocket ships. The effect on the living organism was studied in tests not only in the conditions of the upper atmosphere but in the flight on the rocket itself.

It is always difficult to determine the birth date of any kind of science: yesterday it did not exist and tomorrow it had appeared. But moreover, in the history of any branch of knowledge there is its existence signifying its formation. And as we can say that the work of Galileo can be considered the beginning of experimental physics so we can say that orbital flights of animals marked the birth of space biology; probably,

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everyone remembers the dog Layka sent into space on the second Soviet artificial Earth satellite in 1957.

Thus, in the spring of 1961 we found out that man can complete a space flight; a preliminary analysis showed that everything would go satisfactorily. Nevertheless, because we were talking about a man, everyone wanted guarantees of no unknown circumstances. Therefore, the first flights were prepared with insurance and even, if you wish, with overinsurance. And here one should certainly mention Sergey Pavolvich Korolev. It is possible to realize how much work and anxiety the Design Chief responsible for the first flight of man in space underwent. Nevertheless, he involved himself with all the details of medical and biological servicing of the flight, worrying about maximum reliability. Thus Yuriy Alekseyevich Gagarin whose flight was to last for an hour and a half and who could in general orbit without eating or drinking was given food and other necessary supplies for several days. This was the right idea.

The reason is that we simply did not have adequate information. They knew for example that in a weightless condition disorders of the vestibular apparatus can occur. Whether they would be as we imagined them was unclear.



Dogs began mastery of space exploration. Belka and Strelka in a space cabin.

Another example is space radiation. They knew that it exists but how dangerous it was was difficult to determine in the early times. In this initial period, study of cosmic space itself and its mastery by man occurred in parallel: even before all the properties of space had been studied, flights had already begun. Therefore, protection from radiation on the ships was more powerful than actual conditions required. I wish to note here that scientific work in space biology from the very beginning was founded on a solid academic basis, and the approach to the development of these so-called applied problems was very fundamental. Academician V. A. Engel'gardt, at the time the academician-secretary of the general biology section of AMN SSSR [Akademiya medits'insk'ikh nauk, SSSR, Academy of Medical Sciences of the USSR] devoted his effort and attention to giving space biology and medicine a good start. Academician N. M. Sisakyan assisted greatly in expanding the study and creating new collectives and laboratories: on his initiative, even at the beginning of the 1960's, 14 laboratories of different academic institutions conducted work in the field of space biology and medicine and here powerful scientific teams were concentrated. Academician V. N. Chernigovskiy made a great contribution to the development of space biology and medicine. As the vice president of the Academy of Medical Sciences USSR, he attracted many scientists to his academy to develop these problems. Academician V. V. Parin who particularly studied problems of space physiology and Professor V. I. Yazdovskiy were direct administrators of the first experiments in space biology. One should recall the first director of the Institute of Medical Biological Problems, Professor A. V. Lebedinskiy.

From the very beginning the work was directed by a number of scientists and this provided a good concept of the research and, as a consequence, depth and precision in theoretical foresight which was well supported by the actuality of space flights.

Three of these flights should be particularly noted. One is a biological experiment on the second satellite which showed that living in a space craft can occur without harm in cosmic space. The second of these is the flight of Yuri Gagarin which showed that space does not have a negative effect on the emotional and psychological sphere of man (as has been feared) and that man, as on Earth, can think and work in space flight. And finally, the walk in outer space by Aleksey Leonov: a man in a special space suit existed and worked outside the craft and was able to correctly orient himself in space which was of particular interest to scientists.

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Oleg Georgiyevich Gazenko, at a gathering of journalists at a press conference, holds up the first dogs who returned to Earth from space, Belka and Strelka.

In this group one should include the launched landing of American astronauts on the surface of the moon. The Apollo program also supported certain concepts developed theoretically on Earth. For example, they supported the concept of man's movement on the Moon where the force of gravity is considerably

lower than on Earth. Practice supported the theoretical conclusion that rapid flight through the radiation bands surrounding Earth are not dangerous for man.

By the word "practice" I have in mind not just flights of people. They were preceded by flights of our automatic stations such as Luna and Zond and the American Surveyors which basically surveyed the circumstances on the route and on the Moon itself. On the Zonds, opportunely, life substances were flown to the Moon and returned to Earth in good condition. Illuminating the flight of man in our night was prepared very fundamentally.

As is apparent from the examples presented, the most characteristic trait of the first period of space biology was the search for answers to the main questions. Today, when these answers have been found and in fairly good detail and mainly accepted, the search is in more depth. The present day stage is characterized by a more thorough and precise study of deep fundamental biological, biophysical, and biochemical processes occurring in a live organism in space flight conditions. And it is not simply a study but also there are attempts to control these processes.

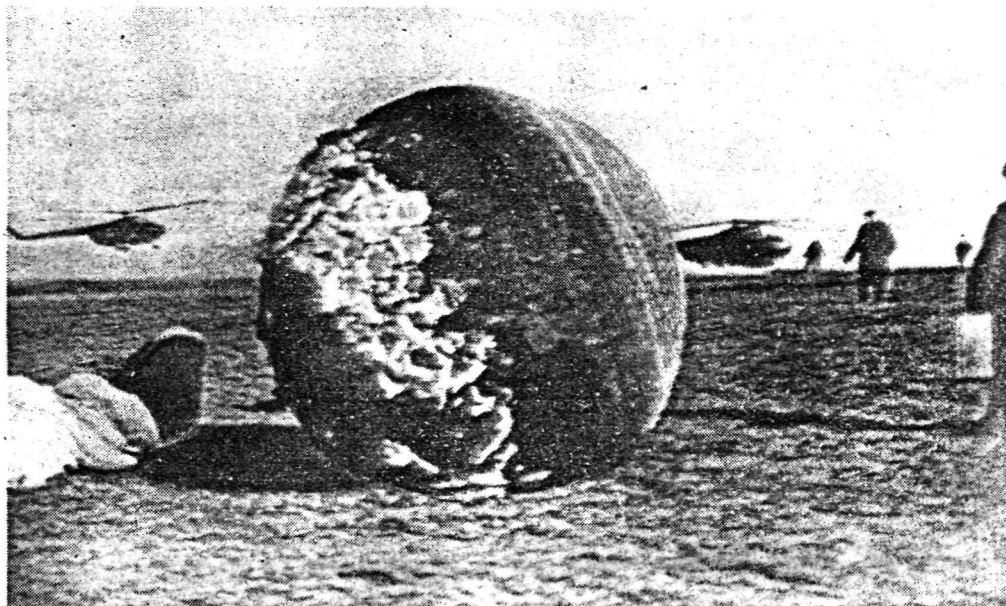
What does this explain? The flight of man in space on a rocket vehicle is different for the state of the organism. Of course, its adaptive possibilities are usually great and flexible, but not unlimited. And then for every adaptation, something else always has to pay. Let us say that the feeling of well being in flight is stabilized but that efficiency in operation is decreased. One adapts to "unusual lightness" in a weightlessness condition, but loses strength in the muscles and rigidity of the bones. These examples are simply surface examples. But obviously, deep life processes follow this principle (and this has been proved). Their adaptation which is not so noticeable in short flights is not apparent. But what if flights become

longer and longer. What will one give up for such adaptation? Can one agree with it or is it undesirable? It is known, for example, that in the blood of the cosmonauts during flight, the number of erythrocytes decreases, that is the red blood cells which carry the oxygen. The decrease is insignificant, and not dangerous but this is in a short flight. How will this process occur in a long flight?

One needs to know all of this in order to set up a prophylactic protective system and to broaden the possibilities for man to live and work in space. And not just for the cosmonauts who are specially selected and trained persons but for scientists, engineers, workers, and possibly artists as well. /36



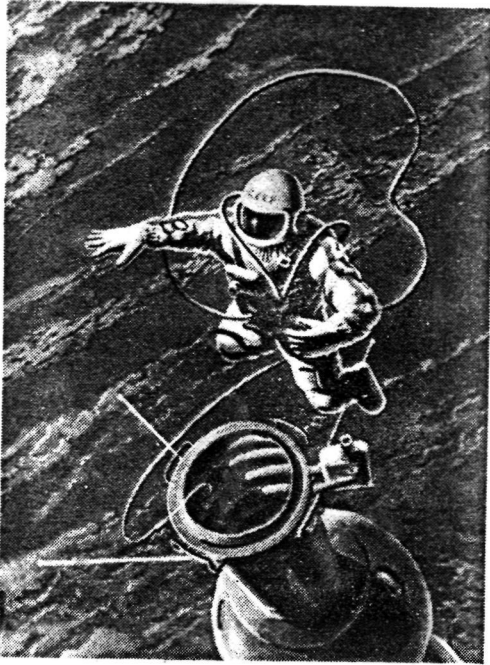
The first flight of man in space. Chief Designer Sergey Pavlovich Korolev gives some parting words to Yuri Gagarin.



The flight of the space craft is successfully completed having passed through the heat of the dense layers of atmosphere surrounding Earth; it has landed.

We are gaining a deeper understanding of "space biology and medicine." In concept, this is an applied science developing, on the basis of general biology data, its recommendations on the methods and behavioral practice of man in space. It has been so from the beginning. But now it has become clear that space biology and medicine are not a product of general biology but all biology as a whole only studying the organism in special conditions of existence. All that man does on Earth, he begins to do in space: eat, sleep, work, rest and in very long flights man will be born and die -- in a word, man will begin to live in a full biological sense in space. And therefore, now we will truly find not one section of biological and medical knowledge which will not be different.

As a result of this, the scale of studies has grown: if one /37 could say that there were literally tens of scientists who participated in the first steps of cosmic biology, today one finds hundreds of institutions and thousands of specialists in different



Cosmonaut Aleksey Leonov leaving the craft and going out into space.

and sometimes unexpected aspects of this field.

For example: the Institute of Transplantation of Organs and Tissues which is directed by the well-known professor of chemistry, V. I. Shumakov, is one of these. What would the study of the healthy organism in special space flight conditions have in common with the extreme measures of saving hopeless patients by organ transplant? But there is something.

The field of mutual interests relates to the problem of immunity

--natural protection of the organism from the effect of bacteria, microbes and other foreign bodies. It has been established that in space flight conditions, immunological protection of the organism weakens. This is due to a number of causes, one of which is the following. In ordinary life we always and everywhere encounter microbes. In the closed space of a spacecraft, the atmosphere is almost sterile and the microflora is considerably less. Immunity becomes practically "inoperable" and "gets out of shape," just as an athlete does when he doesn't train for a long time.

But, with transplantation of organs, one must try to artificially decrease the level of the immunity effect so that the organism will not reject them. Here are general questions that arise: how does the organism behave in these conditions, how does one avoid infectious disease? . . .

There is another field of mutual interests. We propose that with time people will fly and live in space for a long time. This means they can fall ill. Therefore, the need arises, in the first place, to understand which of the diseases can occur and second to provide people in flight with diagnostic equipment and, of course, means of treatment. This can be pharmaceutical but also could be an artificial kidney -- one should not exclude the probability that such methods will be needed in long expeditions. And so we consider along with the specialists of the Institute of Transplantation of Organs and Tissues how to equip future participants of space expeditions with "spare parts" and how "repair technology" could be carried out.

However, operations in space are of course an extreme case. The main role will be prophylaxis and prevention of disease. Nutrition can be of some importance as a means of controlling the exchange of substances and its changes if they occur and also as a means of decreasing nervous and emotional stress. In this way, diet including eating appropriate preparations will, in a definite way, do its job unnoticeably for man; it will not have the character of using medicines. Appropriate studies were carried out for a number of years at the Institute of Nutrition of the AMN SSSR [Akademiya meditsinskikh nauk, SSSR, Academy of Medical Sciences of the USSR] under the directorship of academician of the AMN SSSR, A. A. Pokrovskiy.

There is one more example: the Central Institute of Traumatology and Orthopedics Im. N.N. Priorov (TsITO [Tsentral'nyy institut traumatologii i optopedii imeni N. N. Priorov]) which is directed by AMN SSSR academician M. V. Volkov. The sphere of interest of the institute is the bone-support apparatus of man. Here, not only are methods of treating fractures and bruises and prosthetic methods are studied, but also the nature of change itself in bone tissue. The latter is of interest to us because certain

changes in bone tissue also occur in space. Methods affecting these processes used in space and in the clinic are basically very close to each other.

Hypokinesia which is very widespread in our time, low mobility, is apparent to an even greater degree in space. The condition of a man who has remained in bed because of a two-month illness is comparable to the condition of the cosmonaut who has returned from flight: both must learn to walk on Earth again.

The point is that in weightlessness, part of the blood moves from the lower part of the body to the upper and flows into the head. Moreover, muscles which do not have their usual load weaken. This is comparable to what occurs when lying in bed for a long time. When man returns to Earth (or gets up after a long illness) the reverse process occurs -- blood rapidly flows from above to below which results in dizziness and can cause faintness.

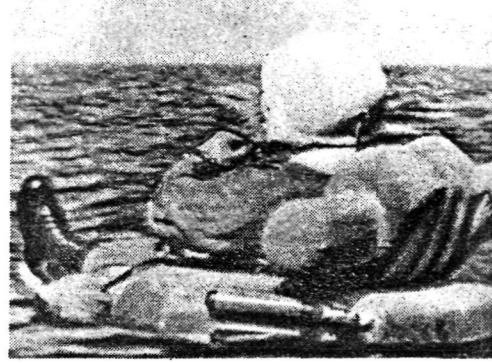
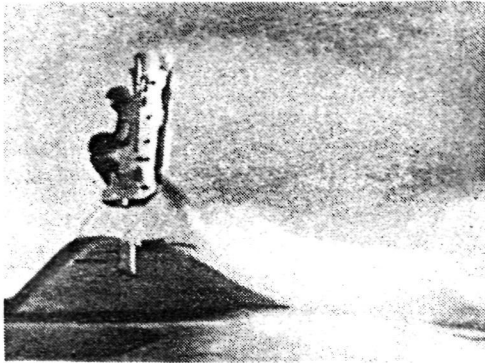
In order to avoid such phenomena the cosmonauts in flight /38 exercise the muscles on a special training unit and use the so-called vacuum system which makes it possible to move part of the blood to the lower half of the body. Having returned from flight, they wear a postflight prophylactic suit for some time which, on the other hand, prevents rapid flow of blood out of the upper half of the body.

Now, similar equipment is used at treatment institutions. At TsITO, the space type training units made it possible for the patient to "walk" without leaving the bed. The postflight suits were successfully tested at the Institute of Surgery Im. A. V. Vishnevskiy using patients who got rapidly onto their feet in a literal sense.

Redistribution of the blood in the organism is not a simple mechanical process but affects the physiological functions and therefore is of some interest both for space biology and medicine and for clinical cardiology. Nevertheless, these questions of regulating blood circulation with a change in the spatial position of the body have not been adequately studied for healthy persons. In combined studies with the Institute of Cardiology Im. A. L. Myasnikov and the Institute of Transplantation of Organs and Tissues, we obtained the first (this work has only begun) interesting data on, for example, how to change pressure in different blood vessels and heart cavities when changing the position of the body in space and on how and at what rate the biochemical composition of the blood flowing from the brain or from the liver or muscles changes with physical load, that is, separately from each organ. This makes it possible to have a deeper understanding of this work and condition.

The studies we are talking about particularly enrich our knowledge of physiology and biochemistry of man; this is an example of fundamental study of the biological existence of man. And the example is not unique.

I have already recalled that in space the number of erythrocytes in the blood decreases in man and that it is possible to analyze the reasons for this phenomenon. Special studies, in particular on the Kosmos-782 biosputnik showed that in space the stability (resistance) of these cells decreases and therefore they break down more frequently than in normal Earth conditions so that their average lifetime decreases. Now, actually one can explain how the stability of the erythrocytes can be maintained. This is important for space but can also be desirable for combatting anemia and other blood diseases.



Before going into space, the cosmonauts undergo a varied course of training which includes simulating Earth and water landings for the cosmonauts.

The fact that space biology participates in fundamental studies of man's organism in a very definite way characterizes the modern stage of its development.

Fundamental studies apply to the basis for further development of actual activities. In our country, the basics of further behavior of man in space apply.

Even now, the requirements for study of cosmic space cause scientists to consider expanding the makeup of specialists flying in space. In the near future we can expect scientists to go into orbit -- space researchers, engineers and organizers of extra-terrestrial production of different materials which cannot be obtained on Earth, workers for collecting cosmic objects and production workers, etc. It is desirable that these specialists, apparently, broaden the fairly narrow "gate" of medical selection today, that is, the formal requirements for the state of health will be decreased, and the volume of preparatory training will be decreased. Besides, one would think that complete safety must be guaranteed and I would say flight safety for these people.

In orbital flight this can be done fairly simply; it will be possible to keep a constant check on the condition of the crew and if necessary one could return a person to Earth in a few hours. Interplanetary flights are another business; they will be considerably more automated. Expeditions to let us say Mars will take /39 2.5 -- 3 years. This means that the approach to organization of such expeditions must be different from flights in orbit. Here, obviously, one cannot decrease the requirements for health when selecting the candidates. Moreover, as we have proposed, the candidates must have not only outstanding health but also certain natural characteristics -- let us say the capability to adapt easily to changing conditions of the environment or a certain reaction characteristic for emergency events.

The capability of the organism to adapt to changes in biological rhythms is very important. The point is that our own rhythms have a terrestrial origin. For example, the 24-hour rhythm is the most important of these and is directly related to the change of day and night. But the Earth's 24-hour rhythm exists on Earth; other planetary days naturally are different and one has to adapt to them. At our institute, a method of biorhythmic selection of cosmonauts was developed: it finds people capable of adapting easily to such a restructuring of the time regime.

Questions involving the moral climate which occur onboard the spacecraft acquire great significance. These are not only personal qualities of people but affect the organization of their work and living habits -- their life in general taking into account requirements including esthetic, of each crew member. This is the most complex circle of questions. For example, there is the problem of free time.

Let us consider that during a flight to Mars, the workload for each crew member amounts to 4 hours out of 24. If we assume 8 hours for sleep, that leaves 12. How to keep them busy? In the limited space of the spacecraft with the crew remaining the same, doing this is not so easy. Books? Music? Films? Yes, but not just any. Music, even well liked, can cause emotional disturbances, increase feelings of homesickness. Books and dramatic films with a tragic plot also can cause negative reactions but the category of adventures, fantasies, travel books, books about polar exploration and speleology in which there is material for comparison and inspiration, will undoubtedly have desirable effects. Solving crossword puzzles and rebus are possible but playing chess or checkers will not be recommended because the element of competition in these games is undesirable in such a situation.

All of these concepts have arisen as the results of studies which have already been carried out. In my opinion, they are very stimulating for an intensive study of the psychology of man and I think that with time when these problems have been adequately developed, they would be very useful in terrestrial practice in the organization of work and recreation for people.

Life support of the expeditions occupies a special place in the development of interplanetary flights. Today, cosmonauts take everything necessary with them in flight from Earth except for partial regeneration of the atmosphere; in some flights, regeneration of water has been carried out experimentally. But for three years this would not be possible for supplies. On an interplanetary ship one would have to create a closed ecological system similar to that on Earth but in miniature which would supply the crew with food, water, fresh air and utilize man's waste materials. The problem is incomparably complex! In actuality, one is talking about competition with nature: while

attempting to reproduce in a laboratory something that was created over millions of years for an entire planet in order to transfer it then to a spacecraft.

This work has been going on for many years at our institute and at the Krasnoyarsk Institute of Physics Im. L. V. Kirenskiy something has already been accomplished but all the same one cannot talk about great successes here. Many specialists generally propose that actual practical success can be achieved after 15 -- 20 years. Of course it is possible that it will be sooner but not by much.

Finally, there are the problems of genetics and reproduction of progeny. At our institute in cooperation with MGU [Moskovskiy gosudarstvennyy univer'sitet im. M. V. Lomonosova, Moscow State University in M. V. Lomonosov] and the Institute of Biology and Development of the AMN SSSR [Akademiya meditsinskikh nauk, SSSR, Academy of Medical Sciences of the USSR] studies are being carried out whose purpose is to determine the effect of weightlessness on embryogenesis and morphogenesis. Experiments, in particular on the Kosmos-782 biosputnik showed that weightlessness does not interfere with normal offspring of insects (fruit flies) but that in more complex organisms -- fish, and frogs -- in a number of cases disturbances and deviations from the normal were observed. This indicates that for normal development in the very first stages of life the fetus must have the Earth's force of gravity and it is possible that this force could be created artificially.

Thus, the problem of long space flights is very significant in our work for tomorrow. And one can rightfully ask the question: how long can man stay in space? It is impossible to answer this question precisely. A number of processes which we cannot yet successfully control occur in the organism during flight. They have not been studied to conclusion and man has not yet

flown for more than three months and we do not know how these processes will occur with longer flight periods. The necessary objective experimental testing and the question of possibilities let us say of a 3-year stay for man in space must be solved in Earth orbit. Only then can we guarantee that such an expedition will be conducted successfully.

But I think that man will not encounter any insurmountable obstacles on this path. This approach can be made on the basis of current knowledge. The space era for man has only begun, in all 20 years, and now we are just selecting the future path which man will follow in space.