JPRS L/10108

10 November 1981

USSR Report

SPACE

(FOUO 5/81)

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APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000400070023-5

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MANNED MISSION HIGHLIGHTS

'SALYUT-7' ORBITAL SPACE STATION LAUNCHING DEEMED UNLIKELY BEFORE EARLY 1982

Paris AIR & COSMOS in French 29 Aug 81 p 43

[Article by Pierre Langereux: "Soviet Orbital Station 'Salyut-7' Will Be Launched at Start of 1982"]

[Text] As disclosed by ex-cosmonaut Alexey Yeliseyev, director of Salyut flights, at a Moscow press conference on 13 July: "The new orbital space station Salyut-7 will not be launched this year."

"Currently, we are continuing operation of the Salyut-6 orbital station, which is docked to the Cosmos-1267 satellite," said Yeliseyev, explaining further that "In preparing for the launching of a new station, we of course take into account the suggestions of the cosmonauts to improve the station, and this takes time."

The USSR, therefore, will not launch its next orbital space station Salyut-7 before the beginning of 1982, in other words, not much before the sending up of a new "international" crew that will include one Soviet and the first French spaceman on a flight tentatively scheduled for May-June 1982.

The orbit of the Salyut-6-Cosmos-1267 orbital complex was just raised once again on 17 July; it is now in a 336-382-km orbit, inclined 51.6°.

It is recalled that Cosmos-1267 was launched on 25 April 1981 and that it was moored to the Salyut-6 station on 19 June. This array, which constitutes a 38-ton station, prefigures the future multimodule orbital stations the USSR proposes to launch "within a foreseeable future," Yeliseyev said.

According to Yeliseyev, Salyut-6 has now been in orbit just a little under 4 years, during 2 of which it has been piloted. During that period, more than 1,600 experiments have been carried out aboard the station. Sixteen crews have boarded it, and there have been 30 moorings, 4 remoorings of spaceships and 3 space walks by cosmonauts, as well as 11 refuelings and resupplyings of food and equipment by Progress spaceships. The total weight of the equipment used aboard Salyut-6--Yeliseyev said--amounts to three tons, of which one ton consists of equipment delivered to it by Progress cargo spaceships.

Around one-third of the time spent aboard it by the successive crews--Yeliseyev said--has been dedicated to the study of terrestrial resources and to other observations related to the earth's environment for use by 22 sectors of the Soviet economy. Seven of the cosmonauts who have flown aboard Salyut-6 have spent more than 100 days aboard it; two, more than 6 months; and one (Valeriy Ryumin), approximately 1 year (in two flights).

These flights have made it possible to "maintain the work capacity of the crews, study the state of health of the cosmonauts in orbit, and make their readaptation to terrestrial conditions easier." However--academician Oleg Gazenko, head of the Medicobiological Institute of Moscow, points out--"There is still much to be done." This has to do particularly with "maintaining the metabolism of calcium by the cosmonauts at normal levels, and safeguarding their bodies' self-protecting mechanisms against infectious diseases." This is by way of preparation for future flights of long duration (1 year) which the Soviets are now planning.

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CSO: 8119/1900

SHATALOV ON PSYCHOLOGICAL PROBLEMS IN LONG-DURATION FLIGHTS

Paris AIR & COSMOS in French 19 Sep 81 p 55

[Text] In a recent article in the USSR Air Force magazine, General Vladimir Shatalov, chief of the Soviet cosmonaut corps, cites a number of problems which need to be solved in order for long-duration flights to be conducted under good conditions. "It seems that the search for an optimum solution will require more than a year." "Nevertheless," asserted Shatalov, "we are not far from permanent operation of orbital stations, that is, twenty-four hour operation all year long by crews who will replace each other directly on board and will regularly receive everything they need."

The problems that must be solved "in the immediate future", specified Shatalov, are essentially to conquer the type of fatigue due to routine, if not from real boredom, which grips cosmonauts at the end of a prolonged stay.

The psychological and psychic factors thus seem to give cause for concern when missions become long.

"The time of active work of a single crew of cosmonauts will, without doubt, always be below the maximum tolerable time of a stay in space no matter how well their work schedule, activity, rest and leisure are designed and organized." Shatalov thinks that "the limited volume of living space, contacts and information produces its effects, as well as the condition of weightlessness. Sooner or later, negative emotions appear and with them fatigue, which has as a consequence a lowering of energy and enthusiasm for work. Under such conditions, rest and a change of conditions are necessary."

Another problem, according to Shatalov, consists in "freeing the cosmonauts from tedious tasks of constantly monitoring the condition of a number of systems which should be handled by automated systems and the ground specialists."

Shatalov also advanced the point of view expressed by certain other specialists, according to whom an excess amount of scientific equipment aboard a station disperses the cosmonauts' strength and thus reduces the economic return.

APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000400070023-5

Finally, Shatalov emphasized the need for offering the cosmonauts the means for varied activity, primarily intellectual rather than manual, "as has been done by the Soviets."

Assessing the past twenty years of manned flights, Shatalov called it "positive." In his opinion, things have progressed in regular fashion in two basic stages. The first consisted in teaching man and space vessels to fly; the second in exploiting these flights in an efficient way.

CSO: 1853/1-P

UDC 629.78.007

MENTAL AND PHYSICAL ASPECTS OF COSMONAUTS' EFFICIENCY IN FLIGHT

Moscow DEYATEL'NOST' KOSMONAVTA V POLETE I POVYSHENIYE YEYE EFFEKTIVNOSTI in Russian 1981 (signed to press 2 Dec 80) pp 2-5, 263-264

[Annotation, foreword and table of contents from book "Activity of the Cosmonaut in Flight and Enhancing Activity Effectiveness", edited by G. T. Beregovoy, USSR pilot and cosmonaut, candidate of psychological sciences, and L. S. Khachatur'yants, doctor of medical sciences, Izdatel'stvo "Mashinostroyeniye", 1800 copies, 264 pages]

[Text] This book examines the theoretical and practical issues related to increasing effectiveness of spaceship crew activity. It studies the problems of engineering psychology in the interests of providing for safety in space flight. The unique conditions of flight in space, the specific elements of a cosmonaut's activity, his mental states and methods for diagnosing and controlling them, are modelled in this book.

The book is intended for engineering and technical personnel and medical personnel engaged in cosmonautics, ergonomics and industrial psychology.

FOREWORD

The development of cosmonautics is of tremendous significance in studying the earth and the near-earth atmosphere, in finding solutions to major national economic problems. Already the term "cosmization of production" has come into common use. by which is usually meant the process of people's deliberate activity aimed at direct or indirect use of the natural scheme of things in outer space in the interests of social production.

Cosmization of production came about even prior to man's first flight into space. Designs were developed in laboratories for utilizing the unusual conditions found in space for earth-related endeavors. Many of these designs are in use today--systems for global communications and celestial navigation in space, projects in the sphere of meteorology, oceanography, etc.

However, along with the development of space technology and the increasing complexity of space research programs, responsibility also grows for the man who must participate as an independent element in operating the diverse, semi-automatic systems for spacecraft guidance. In some instances, a reduction in man's reliability, as one element in the total system of control, can lower the operational quality of the system right up to the point where execution of one flight operation or another becomes completely impossible.

In solving today's problems and those of the near future, particular significance must be attached to studies related to stability of the human organism when confronting space flight conditions, and increasing man's reliability, especially when he is controlling complex space-technology equipment.

We see three basic paths for research, which, if followed, will help to achieve the overall purpose--increasing the reliability and effectiveness of space flight on the whole. Firstly, we must optimize the system for training cosmonauts and the scheme of operational activity on board the spacecraft. Secondly, we must enhance the level of technical maintenance for on-board equipment and improve its operational level. Thirdly, we must effect operative guidance of the cosmonaut's mental state during flight, and of his work efficiency.

Efforts in these three areas are completely different with respect to what methods are to be used in their accomplishment, whose area of expertise is involved, and what form of implementation recommendations obtained will take. Those directly involved in accomplishing these efforts--the USSR pilots and cosmonauts, the engineers, doctors, biologists and psychologists, the technique specialists and designers--are well aware of this. In spite of a diversity in procedure and technique, the areas of research we have proposed to the reader are logically related and mutually interdependent.

Material cited in the book's first chapter describes a number of new directions in space research, and the basic principles and methods for maintaining a cosmonaut's effectiveness during flight. Despite the fact that it is based on serious experiment, much of this material is open to debate. This can be explained, basically, by the non-traditional nature of the problems being touched upon, especially those that concern efforts dedicated to finding new procedures and techniques for studying man's activity, work that involves the theoretical particulars of cosmonaut preparation, forecasting the psychophysiological problems the future will bring, and projects that concern the use of psychophysiological feedback, as well as several other matters. Material is cited here for the first time with respect to regulating the mental state of the operator. Chapters two and three discuss optimization of the activity of the cosmonaut involved with the spacecraft's guidance system and matters of technical maintenance. The material in these chapters is of acute practical significance not only for conditions of space flight, but for other occupational conditions as well. Finally, chapter four contains material which, to one degree or another, describes the human operator's resistance to outside interference, and ways to optimize this resistance in the interest of enhancing safety in flight.

The book is the fourth in a series on this subject ("The Human Operator in Space Flight", Moscow: Mashinostroyeniye, 1974; "Particular Features of the Cosmonaut's Activity in Flight", Moscow: Mashinostroyeniye, 1976; "Man and Celestial Navigation in Space", Moscow: Mashinostroyeniye, 1979). This book differs from its predecessors in that, along with describing the dynamics of a cosmonaut's work efficiency in flight, it also treats specific measures for optimizing it.

In conclusion, we will note once again that the basic goal of this book is to generalize the firsthand experience the authors have gained over the course of space flight preparation and execution, and during their specific participation in solving the problems presented by a psychophysiological assessment of space technology.

The book is intended for specialists in the engineering and technical sphere, and for medical personnel working with manned space vehicles. It may be useful to readers who are students of ergonomics and industrial psychology, and also to all those interested in what the cosmonaut does--a complex sphere of human activity that takes place in the unusual conditions of space.

We invite the opinions and comments of any reader who might have questions with regard to material presented in this book, and request that he forward same to the publisher.

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CSO: 1866/155

LIFE SCIENCES

INVESTIGATION OF MUTAGENIC FACTORS OF SPACE FLIGHT

Moscow MUTAGENEZ PRI DEYSTVII FIZICHESKIKH FAKTOROV in Russian 1980 (signed to press 10 Nov 80) pp 206-223

[Article by E. N. Vaulina from book "Mutagenesis Induced by Physical Factors" edited by Academician N. P. Dubinin, Izdatel'stvo "Nauka", 1300 copies, 225 pages]

[Text] Development of rocket building and cosmonautics has caused a tremendous upheaval, not only in a number of technological branches of science, but development of many basic sciences, including biology. Space biology and such branches thereof as space genetics, space radiobiology, space microbiology, etc., were conceived and began to develop. In the 18 years (1960-1978) of development of biological research aboard space vehicles, the tasks, objectives and directions of the problem of "space biology" were completely formed, and determination was made of the objects and methods used in such research.

Before we turn to further discussion of the problem, its inception and development, we should define the concepts that we impart to the terminology used: "space," "space flight," "cosmic space" and "factors of space flights and planets."

At the present time, the word "space" [cosmos] has two meanings: the broad one referring to the universe considered as a single entity governed by common laws that are studied by the discipline of "cosmology," and the second meaning, which refers to everything beyond earth and its atmosphere (Frank-Kamenetskiy, 1976). In the latter sense, the concept of "space" is set against the concept of "earth" and it is used in such terms as "space flight," "cosmic space," etc. We use these terms in the same sense.

Then we must make a distinction between the concepts of "conditions of space flight, space and planets" and "factors of space flight, space and planets." The former refers to the living conditions of an organism and the latter to the parameters of these conditions.

Beyond earth, the organism finds rather specific living conditions, and they are different in different cases; for example, conditions during a space flight in a near earth orbit, or flight to other worlds and conditions of planets in our galaxy and their satellites. In virtually all cases, with the exception of planets that have an atmosphere that is suitable for "terrestrial life," these conditions will constitute artificial ecological systems that are closed to some extent or other. And while these conditions on planets with an atmosphere that is compatible with life may differ in composition of atmosphere and barometric pressure, level of gravity, magnetic field and radiation, and perhaps a number of other parameters, in artificial ecological life support systems the factor of limited space is added to these differences. A number of the parameters of artificial ecological systems can be regulated by man at will, for example, temperature. Others, however, can be approximated to customary terrestrial features only relatively, either because of the technical difficulties or virtual technical impossibility thereof. The composition of the gas environment, magnitude of gravity and magnetic fields, radiation situation, etc., are such parameters. In terrestrial biology, both these and a number of other features that determine the ecological system of the "globe," i.e., the "biosphere," are generally considered to be relatively stable and unchanging. A quantitative and qualitative change in some factor is perceived as disruption of the normal course of biological processes. The results of these changes are viewed as special cases of biological phenomena occurring under the influence of some environmental factors or other. The study of these phenomena often leads to development of new directions in biology. For example, in genetics, the directions of "radiation genetics" and "chemical mutagenesis" appeared. The values of the variables become the principal environmental factors during a space flight or in space. For example, gravity and magnetic fields may change from zero to values that exceed significantly those of the fields of earth, whereas in the spectrum of ionizing radiation there is appearance of high energy hadrons that have virtually no effects on organism on earth. Thus, the biosphere of a space flight and space would have qualitative and quantitative differences from the biosphere of earth. The basic difference in a number of physical processes in the presence of altered gravity or in absence thereof may affect physiological processes that determine the function of organisms, and alter heat, mass and energy transfer. This would create specific conditions and put a certain imprint on genetic processes that occur under such conditions in terrestrial organisms. It should be stressed once more that the most important element of these differences, in our opinion, would be the variable nature of a number of factors that are perceived as constant in earth's biosphere. The practice of cosmonautics and exploration of cosmic space raises, first of all, the question of nature of processes of inheritance and behavior of genetic systems during space flights and in space. We shall have to consider the genetic knowledge accumulated on earth from a new vantage point to answer it.

At the present time, there are three distinct stages of development of biological research in space: the first, up to 1960, to the first experiment aboard an artificial earth satellite; the second, up to 1971, to development of the Salyut orbital station; and the third, which is developing now and related to performing research on orbital and planetary stations. We should note one aspect of development of space genetics, its close relationship to technological progress. It was generated by the latter, it appeared, is developing and will develop only as a result of appearance, development and refinement of rocket technology and means of interplanetary communication [or travel]. The stages of development of space biology follow, to some extent, the stages of development of cosmonautics, and because of the rather specific technical conditions and possibilities, each of them has different goals and tasks. Thus, at the first stage of development of space genetics, factors were discovered that affect organisms during space flights, and methodological approaches were developed to simulate them and analyze the findings. The second stage of development of research had the objective of genetic marking of the routes of space flights and investigation of the effects of flights on genetic structures. The third stage of research, which began in 1971, will permit analysis of the mechanism of action of flight factors on biological systems, on the basis of knowledge about environmental conditions of space flights and space, as well as development of methods for protecting them and solving such an important problem for cosmonautic practice as creation of life support systems on the basis of vital functions of organism. It is impossible to perform this task without definition of the genetic bases of these artificial ecological systems and development of methods of genetic and breeding work to create new forms of organisms that would be components of these systems.

The source of development of space genetics is closely linked with the source of radiation genetics, which emerged in the first quarter of our century.

As we have already noted, the stages of development of biological research in space are closely linked with the development and advances in rocket building and cosmonautics. We can also note the same relationship with regard to investigation of factors that affect organisms in space.

The first factor, cosmic radiation, drew the attention of researchers long before the start of the space age of mankind. The question of necessity of studying the genetic role of cosmic rays resulted from two major scientific discoveries at the start of our century: discovery of ionizing radiation in cosmic space (Rossi, 1966) and proof of the mutagenic activity of ionizing radiations (Nadson, Filippov, 1925; Muller, 1926). However, at first cosmic rays drew the attention of researchers only as a probable factor of evolution. Later on, in the 1940's, in connection with the development of rocket building and appearance of the possibility for man to penetrate into space, the question also arose as to the biological effects of cosmic rays. The first genetic experiments conducted in 1935 in balloons yielded a negative result (no differences were found between the control and experiment), and for a long time there was no interest in this problem. In the early 1950's, interest in the effects of cosmic radiation, particularly its heavy component, on organisms was again revived abroad. The technical refinement of balloons [aerostats] and rockets, which made it possible to increase the altitude and duration of exposure of biological objects in space, and development of high altitude aviation served as an impetus for this interest. While cosmic radiation was the main factor affecting biological objects in the experiments on balloons, a new group of factors appeared in those on rockets: dynamic factors (due to the dynamics of craft flight), the effects of which on biological objects could be considerable. Although weightlessness was present in these experiments, it had not yet drawn the serious attention of researchers. However, with the appearance of artificial earth satellites and orbital stations, with increase in duration of manned space flights, the question of the biological role of weightlessness was advanced to the fore in research on space biology.

At the present time, it is believed that the following factors may affect organisms in space flight: those characterizing cosmic space as the habitat, determined by flight dynamics of the craft and those determined by the internal environment (biosphere) of the flying vehicle itself.

The first group of factors includes the high degree of rarefaction of the atmosphere, ultraviolet and infrared rays, radiowave and microwave radiation, ionizing radiation and others. Of these factors, the ones of interest to biologists who conduct experiments aboard space vehicles are cosmic rays, a factor that could affect organisms in a spacecraft, since it penetrates through the craft's shell. The inside of the spacecraft is insulated against other types of radiation, in some way or other.

The second group of factors, determined by dynamics of flight, consists of so-called dynamic flight factors, which include accelerations (linear, radial and angular), vibration, noise and weightlessness.

The third group refers to factors that are related to being in a spacecraft: isolation, artificial gas atmosphere, altered biological rhythm, artificial electromagnetic fields from instruments, etc.

Cosmic rays are a flux of high energy nuclei and secondary radiation that they form in earth's atmosphere and in a spacecraft, which includes all elementary particles known to date. Primary cosmic rays have greater penetrating capacity than all forms of radiation known in laboratory experiments. At the present time, it is generally believed that the flux of primary cosmic rays consists of about 85% protons, 13-14% α-particles and 1-2% particles with a charge of 3 or more. The probable dose levels of ionizing radiation during long-term space flights are listed in Table 1.

Table 1. Probable doses of ionizing radiation to crews during long-term space flights (2 g/cm^2 shield thickness) [9]

Type of ionizing radiation	Irradiation conditions	Dose, rem per day	month	year
Galactic cosmic	Chronic, isotropic	0.07-0.14	2.2-4.3	25-52.6
From solar bursts*	Divided doses, 5-10 times/year, unilateral	From 0 to $80-15\cdot10^3$	$80-15\cdot10^3$	$800-15\cdot10^4$
From near-earth and near-planet radiation belts*	Single dose (when flying through belts) bilateral	2-4	2-4	2-4
From radioactive substances contained in materials of spacecraft furnishings, cosmonauts and foods, i.e., radiations that are part of the natural background on earth*	Chronic, nonuniform over body	0.00024	0.0072	0.086
	Chronic and recurrent	From 0.07 to $80-15\cdot10^3$	$82-15\cdot10^3$	$825-15\cdot10^4$

*RBE was taken as 1 in the calculations.

The effects of dynamic flight factors (other than weightlessness) are related essentially to the phases of ascent, descent and maneuvering the spacecraft. These factors can be simulated in the laboratory. Since their range is very wide in each vehicle, it is difficult to reproduce it exactly in every given experiment. In model experiments, one generally uses tape recordings of the modeled process (Shipley, Maclay, 1965).

Noise and vibration are similar phenomena. Vibration refers to the mechanical oscillations of different shaped resilient bodies. The frequency of vibrations ranges from one to several thousand hertz and is characterized by the frequency, amplitude and magnitude of accelerations. The noise is an acoustical, nonharmonic sound characterized by a complex time structure and specific property of affecting the organism. When the engines of the spacecraft are in operation, a noise of up to 180 dB occurs. There is a wide range of sonic oscillations, from a few hertz to 20,000. Vibration to which the living organism is exposed is characterized by frequency, amplitude and so-called vibroacceleration, i.e., change in velocity per unit time (m/s^2), or vibro-overload, expressed in units that are multiples of free-fall acceleration G. During a space flight, the organism is exposed to vibrations at frequencies of 2 to 15 Hz and vibroaccelerations of up to 1 G.

Acceleration (G force, overload, in aviation and space medicine) is the vector that determines the rapidity of change in velocity according to magnitude and direction. The magnitude of acceleration is proportionate to the force acting on a body and inversely proportionate to its mass, while its direction coincides with the vector of force. When a space vehicle takes off and when it is being maneuvered, so-called long-acting acceleration appears. Its magnitude can reach 10 G. After ejection, landing on earth and in emergency situations, "impact acceleration" occurs, which is notable for its brief duration (less than 1 s) and high build-up rate (from several hundred to several thousand G per second).

Weightlessness is a qualitatively new factor that is not present on earth and the organism is exposed to it during a flight. Weightlessness is defined as a state of a mechanical system, in which the external forces acting on the system do not elicit reciprocal pressure of system particles upon one another. It is very difficult to simulate weightlessness on earth. Weightlessness lasting 1-3 s can be obtained on elevators, swings and "Roman tower" type devices. When aircraft fly over a parabolic curve a state of weightlessness lasts for up to 50 s. This is infinitesimal for biological experiments. In a spacecraft circling around earth weightlessness lasts for a long time. It is among the habitat features of the craft.

Thus, dynamic flight factors affect an organism in space flight: acceleration, vibration, noise and weightlessness, as well as space factors--radiowave and microwave radiation and ionizing radiation--and factors referable to the internal environment of the flight vehicle: isolation in a small space, artificial gas atmosphere, altered biological rhythm, artificial electromagnetic fields and others.

An inactivating mutagenic or teratogenic action has been demonstrated in ground-based experiments for each of these factors, perhaps with the exception of weightlessness and cosmic radiation. At the same time, the combination of these factors in qualitatively and quantitatively different variants may have a different effect on organisms. For example, it was demonstrated that exposure to vibration prior to radiation enhances the radiation effect, whereas exposure to vibration after radiation attenuates the latter (Vaulina, Kostina, 1973).

At the same time, it is virtually impossible to simulate in ground-based experiments such factors as weightlessness and certain components of cosmic radiation (hadrons). For this reason, one has to conduct experiments aboard space vehicles during orbital flights in order to demonstrate the mutagenicity of flight factors.

We cannot fail to mention here the distinctions of biological experiments conducted aboard a space vehicle, as compared to ordinary laboratory experiments on earth. In addition to the above-listed complex set of factors, concomitant factors may affect experimental objects, such as temperature, humidity and others. Experiments almost always involve storage of material before and after exposure to the tested factors. Storage time sometimes varies from several hours to several dozen days in different experiments.

Extensive biomedical research is conducted regularly aboard artificial aircraft. Monkeys, dogs, rats, mice, guinea pigs, amphibians, fish, cultures of cells from different tissues of man, animals and plants, pieces of human and rabbit skin, preparations of DNA and enzymes, Drosophila, Habrobracon, Tribolium, amoebae, bacteria, actinomycetes, yeast, chlorella, chlamydomonads, seeds of a number of higher plants (peas, nigella, corn, wheat, onion, lettuce, carrot, tomato, cucumber, barley, Crepis, arabidopsis, pine, spindle-tree and others), pollen of higher plants and vegetating plants (tradescantia, pepper, Chinese cabbage, pea, potato, onion) have been flown aboard spacecraft. At the present time, the quantity of objects used in genetic experiments on spacecraft has been reduced. Those were chosen, for which methods of exposure and treatment have been developed, and for which life support equipment and apparatus for experiments in weightlessness have been created. The principal objects are microorganisms, lower plants (chlorella, chlamydomonad), higher plants (Crepis, Arabidopsis, barley, lettuce, pea), insects (Drosophila, Habrobracon, Tribolium), fish, mice and rats.

Experiments were performed aboard a number of manned and unmanned space vehicles with various orbital parameters and different duration of flights, ranging from a few hours to a few months (Table 2).

It should be noted here that biologists who experimented aboard spacecraft had to resolve a number of technical and methodological difficulties. One of the distinctions of the experiments is the limited weight, dimension and power consumption of equipment, and participation of an experimenter. Even the simplest steps, for example, soaking seeds to allow them to sprout and fixing seedlings, or feeding animals and watering plants, have to be performed by special equipment. Moreover, in weightlessness all liquid or loose substances used in the experiment or excreted by organisms have to be isolated from contact with the atmosphere of the spacecraft cabin. For this reason, most objects must be kept in sealed instruments or containers, and they must often have their own life support system. And, while this refers to packages and boxes for dry seeds, for the Drosophila we have to deal with heat-controlled containers with nutrient medium and air exchange, and for mice a complex system with delivery of feed and oxygen and removal of gaseous, solid and liquid wastes. All such restrictions and distinctions referable to performing experiments complicate them considerably and make it difficult to interpret the obtained results.

The obtained experimental results are indicative of the direct and combined effects of various flight factors.

The dynamic factors of lift-off and descent of the craft (a set that includes accelerations, vibration and noise) are more or less similar in duration, magnitude and quality of effect in different experiments, at least in experiments performed on the same type of spacecraft. However, their effects in different experiments may be altered due to a change in duration of the interval between lift-off and landing, i.e., between the first and second exposure to the dynamic factors. Moreover, during this period organisms are in dynamic weightlessness and may be exposed to cosmic radiation, which makes its mark on the observed effects.

Table 2. Biological experiments during space flights

Types of space vehicles	Number of vehicles	Exposure time, days	Biological objects carried aboard the spacecraft
Satellite spacecraft, USSR	2	1-7	Microorganisms, lower and higher plants, insects, mice
Vostok, USSR	6	1-7	Microorganisms, higher and lower plants, insects
Voskhod, USSR	1	1	Plants
Zond, USSR	4	7	Lower and higher plants, insects
Soyuz, USSR	8	2-18	Higher and lower plants, insects, roe of fish and amphibians
Cosmos, USSR	10	2-60	Microorganisms, higher and lower plants, insects, fish roe, rats
Salyut orbital stations, USSR	4	18-408	Microorganisms, lower and higher plants, insects, roe of fish and amphibians
Biosatellite, USA	1	2	Microorganisms, protozoans, higher plants, insects
Gemini, USA	2	3	Lower and higher plants, human leukocytes
Apollo, USA	2	8-10	Microorganisms, crustaceans
Skylab, USA	1	30	Crustaceans, fish roe
Soyuz-Apollo, USSR-USA	1	6	Microorganisms, lower and higher plants, fish roe

It has been demonstrated that the dynamic factors of lift-off and descent of the spacecraft induce an increase in incidence of chromosomal aberrations (Arsen'yeva et al., 1962; Demin, 1964; Vaulina, Kostina, 1973), incidence of embryonic lethals and chlorophyll mutations in Arabidopsis seeds (Anikeyeva et al., 1978) and the incidence of dominant lethals and crossing-over in the Drosophila (Parfenov, 1964, 1965); they inactivate respiratory enzymes in cells (Imshenetskiy et al., 1974). Vibration lowers mitotic activity of bone marrow cells in mice, it causes adhesion of chromosomes (Arsen'yeva et al., 1961, 1965) and alters substantially the state of the nervous and hemopoietic systems ("Man in Space," 1974; Antipov, L'vova, 1978). Several studies revealed that vibration can alter appreciably the organism's reaction to radiation. The direction and degree of changes depend on time and order of exposure to the factors (Vaulina, Kostina, 1973).

For researchers, the most interesting dynamic flight factor is weightlessness. This is the factor whose contribution to the effect has still not been sufficiently studied, since it is virtually impossible to conduct model experiments that would preclude other factors. Consequently, the conclusions concerning the effects of weightlessness on biological objects are made on the basis of flight experiments, which include a set of factors that affect the organism.

It has been found that weight may have both a direct and indirect mutagenic effect. The direct effect of weightlessness on chromosomes was first demonstrated by N. L. Delone in Tradescantia microspores (Antipov et al., 1965; Delone et al., 1966, 1968).

Several experiments, conducted with the help of cosmonauts P. R. Popovich, V. F. Bykovskiy and B. B. Yegorov, involved fixing of Tradescantia buds at different stages of exposure to weightlessness. About 3% anomalous mitoses were demonstrated, which had not been observed in the control. These disturbances consisted of change in orientation of chromosomes (type III aberrations), retardation of unseparated chromosomes (type IV), multipolar mitoses (type V) and nonseparation of chromosome set (types I and II) (Figure 1). The authors succeeded in demonstrating unequivocally that this effect is a function of duration of weightlessness (Figure 2). Analogous mitotic disturbances were demonstrated by American researchers in microspores, megaspores and root tip meristematic cells of Tradescantia (Sparrow et al., 1968, 1971).

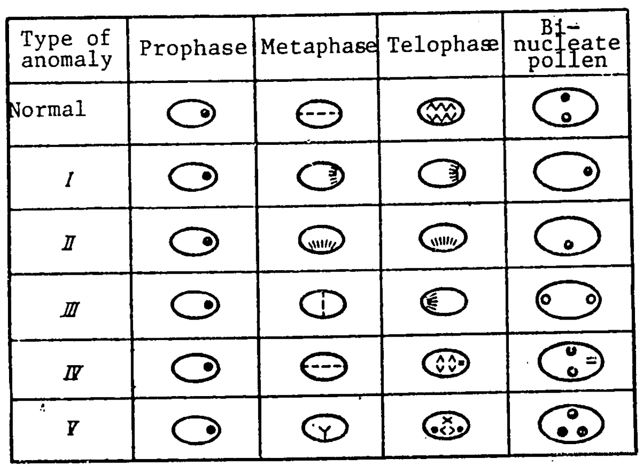


Figure 1. Anomalous mitoses observed in Tradescantia microspore cells (Antipov et al., 1965). Explained in the text

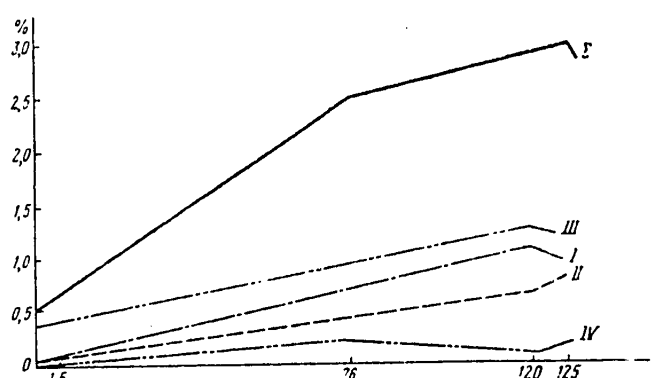


Figure 2. Incidence of mitotic disturbances (%) in Tradescantia microspores as a function of time of cell development in weightlessness (Antipov et al., 1965). Σ--Total number of mitotic disturbances; I-IV--different types of disturbances

Weightlessness makes its contribution to the other effects elicited by flight factors, but it is an indirect effect on genetic structures.

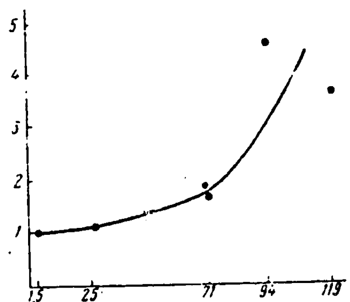
At present, numerous studies have established that weightlessness has an adverse effect on the functions of a multicellular organism. Changes are observed in the sensorimotor system, skeletomuscular, cardiovascular and endocrine systems, and fluid-electrolyte balance (Pestov, Geratevol', 1975). It was demonstrated that metabolism of unicellular organisms also changes in weightlessness. However, the effect may be dual here, both positive and negative, depending on the prior state of the culture: growth of a culture in a good state is enhanced and that of a culture in a poor state is depressed (Kordyum et al., 1976) by weightlessness.

Perhaps such differences in function of macroorganisms and microorganisms in weightlessness can be attributed to the difference in attitude of these groups of organisms to the gravity field. V. I. Vernadskiy wrote (1940): "In essence one can and must assume that life is manifested in two physically different spaces. On the one hand, it is manifested in the field of gravity, in which we live and which is the most ordinary for us. But this gravity field, where the entire set-up of phenomena is determined by gravity, does not cover all aspects of life. The minutest organisms reach a size close to that of molecules, though the order of magnitude is different. These organisms, which are smaller in diameter than one hundred thousandth of a centimeter, come into the field of molecular forces, and their life and phenomena related to it are determined not only by universal gravity, but the radiations that surround us everywhere, which could extinguish for such organisms the living condiitons created by gravity" (p 141).

However, altering the functions of organisms in some way or other, weightlessness elicits more complex genetic changes.

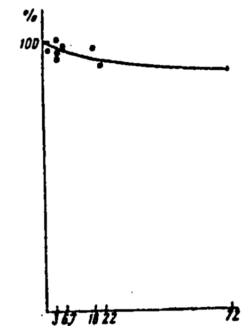
Evidently, the postflight increase in phage-producing activity of a lysogenic culture of E. coli K-12λ, which is correlated with duration of flight, constitutes such an indirect effect of weightlessness (Zhukov-Verezhnikov et al., 1965, 1966). In these experiments, induction was considerably higher than the level that could have been induced by the dose of ionizing radiation observed during the flight, while vibration per se neither induced phage production nor influenced phage production elicited by ionizing radiation (Figure 3). This could also explain the decrease in postflight survival of an inactive chlorella culture, which was related to flight duration (Figure 4) (Vaulina et al., 1967, 1971; Shevchenko et al., 1967; Vaulina et al., 1968, 1971; Anikeyeva, Vaulina, 1971; Dubinin et al., 1973). Several studies have demonstrated the effect of weightlessness on some physiological and morphological parameters of chlorella (Semenenko, Vladimirova, 1961; Kordyum et al., 1974; Kordium et al., 1976).

On the other hand, it should be borne in mind that the causes of spontaneous mutations are referable to the natural environmental conditions and metabolic distinctions. As we have already noted, the absence of gravity and weightlessness in flight alter significantly the environmental conditions of organisms and alter their metabolism. This cannot fail to affect the level of spontaneous mutations: after the change in metabolism there is also a change in level of spontaneous mutations. Thus, there was a 1.5-4-fold increase in incidence of chromosomal aberrations in dry Crepis capillaris seeds during space flights, as compared to the ground-based control (Table 3), and it did not demonstrate a clearcut relationship to flight duration. The incidence of aberrations in C. capillaris seedlings in weightlessness was 2-7 times higher than the spontaneous rate on earth, and it was also unrelated to flight duration (Table 4).



Time in flight, hours

Figure 3.
Degree of induction of E. coli K-12(λ) as a function of space flight duration (Zhukov-Verezhnikov et al., 1965, 1966)



Flight duration, days

Figure 4.
Survival rate of chlorella (%) as a function of flight duration

Table 3. Modification by extreme factors of the effect of exposing air-dried Crepis capillaris seeds to γ-radiation

Spacecraft	Exposure to factors, days	Ratio of experimental to control incidence of chromosomal aberrat.: without γ-radiation	γ-rad. before other factors	γ-rad. after other factors
Soyuz-16	6	1,6	1,45***	0,84*
Soyuz-19	6	1,6*	1,19	0,60***
Salyut-5	8	1,71	0,71*	0,78
Soyuz-9	18	4,13***	1,06	0,67*
Cosmos-782 g 0		1,24	1,78*	0,59*
Cosmos-782 g 0,3	21	1,31	1,89*	0,81*
Cosmos-782 g 1		1,12	1,65*	0,49*
Salyut-5	19	0,84	1,30***	0,73***
Salyut-5	50	1,89	1,00	1,08
Cosmos-613	60	1,41	1,32***	0,77***
Salyut	72	1,36	1,34***	1,00
Salyut-4	92	3,82***	0,69***	1,27*
Salyut-5	249	3,81*	0,94	0,65***
Vibration + accelerations	9 min	6,13	1,02	0,62

* t = 1,96 – 96%.
** t = 2,58 - 99%.
*** t = 3,29 – 99,99%.

Table 4. Incidence of chromosomal aberrations in C. capillaris seedlings that developed in weightlessness after air-dried seeds were in weightlessness for different periods of time

Variant	Number of roots examined	Meta-phases examin.	Damaged meta-phases	Incidence of chromosomal aberrations, %±m
Ground-based control	26	4266	9	0,21±0,01
Seeds in flight for 20 days	27	4338	19	0,44±0,12*
Seeds in flight for 229 days	16	2131	33	1,55±0,26**

* $P \leq 0{,}05$.
** $P \leq 0{,}001$.

This lack of relationship of the effect to duration of weightlessness indicates that the latter has an indirect effect (through change in metabolism) on the process of occurrence and expression of mutations. This is also indicated by the modifying properties of weightlessness. After exposing seeds to weightlessness, changes were found in the cells that affect processes of expression of mutations and sensitivity of chromosomes to mutagenic factors. Thus, after the flight aboard the satellite, sensitivity of C. capillaris seeds to ethylenimine was increased by over 2 times (Dubinina, Chernicova, 1968; Dubinina, Chernikova, 1970). An analogous result was obtained with barley seeds (Garina, Romanova, 1970, 1971). Many researchers have demonstrated enhancement of the effect of preflight exposure of seeds to radiation (Nuzhdin, Dozortseva, 1967; Farber et al., 1971; Dubinin et al., 1973). Since vibration does not enhance the effect of prior irradiation of seeds (Vaulina, Kostina, 1973) and the radiation dose observed during the flights was low, the effect is related to weightlessness (Vaulina, 1976).

Experiments involving exposure of objects to different doses of γ-rays in weightlessness revealed that both synergistic and antagonistic effects can be observed in the interaction between flight factors and radiation. Tradescantia irradiated in weightlessness showed an increase in quantity of abortive pollen, as well as incidence of micronuclei in pollen and number of staminal pili with arrested growth (Sparrow et al., 1968, 1971). In this case, the Tribolium demonstrated an increase in number of specimens with wing abnormalities and incidence of dominant lethals in females. The author believes that this occurs due to less efficient function of repair systems in weightlessness (von Borstell et al., 1971). In the Drosophila, there is an increase in number of specimens with deformed thorax and wing anomalies, incidence of chromosomal breaks and translocations between the 2d, 3d and 4th chromosomes and in number of sex-linked recessive lethal mutations (Oster, 1971). The author believes that enhancement of the mutagenic effect of ionizing radiation in space could be attributable to the modifying effect of weightlessness, which apparently makes it difficult for chromosomal breaks induced by radiation to be repaired. In favor of this hypothesis is the significant number of chromosomal translocations in spermatogonia of the Drosophila, which are extremely rare on earth. Vibration lowered the radiation-induced incidence of translocations in the Drosophila (Browning, 1971).

However, a different effect was also observed in organisms irradiated in space. For example, in the Drosophila there was less loss of y-chromosome markers, as compared to Drosophila irradiated on earth (Reynolds, Saunders, 1971). It was demonstrated that in neurospores there was a lower incidence of mutations in the flight variant than ground-based control, due to reduction in number of spot mutations, whereas the incidence of deletions did not change (de Serres, Webber, 1971).

Among the factors of the inside environment of a flight vehicle, the following may be of interest: the artificial gas atmosphere and its different components, electromagnetic fields from instruments.

This is the least studied group of factors. It is assumed, on the basis of some ground-based experiments, that they may have an influence on genetic structures of organisms, but no studies have been made specifically to determine the mutagenicity of the craft's environment or its components. Experimenters have tried to rule out the effects of these factors with various technical procedures--heat control, sealing and use of protective containers. However, this has not always been successful.

During a long-term space flight, the dose absorbed by living objects in a spacecraft consists of galactic cosmic radiation, radiation from solar flares, earth's radiation belts, radiation from various instruments and equipment aboard the craft and secondary radiation occurring when heavy charged particles in the shell of the craft and other equipment are stopped.

The biological effects of light high-energy nuclei are virtually the same as of such forms of radiation as, for example, gamma rays and x-rays, whose effects have been well-studied in radiation biology. The biological effects of heavy nuclei have not been sufficiently investigated, since it is difficult to simulate them in experiments on earth.

In spite of this, a number of distinctions have been demonstrated with respect to the action of heavy ions. It was shown on mammalian cells that the effectiveness of each accelerated ion may be about 1000 times greater than the effectiveness of its low-density ionizing analogue with low LET. The relative biological effectiveness of protons with energy of 660 MeV, estimated from the incidence of chromosomal aberrations in the root meristem of seedlings, was found to be 1 to 5.5 for different plants (Grigor'yev, Tobias, 1975). Heavy ions induced a large area of damage (groups of cells) as a result of the action of one particle (Leith et al., 1971). It was noted that there was nonuniform distribution of absorbed energy due to generation of secondary particles. This can be seen from the significant scatter of different experimental values of RBE (Akoev et al., 1971). Prolonged retention of the effects of exposure to heavy ions was observed. Thus, the high incidence of chromosomal aberrations in mammalian liver cells persisted for several months after exposure to carbon ions (Grigoriev et al., 1973). The same was observed in plants (Heinze et al., 1972; Todd et al., 1973). The survival curves for cells and tissues exposed to heavy ions show multiple hits (Grigor'yev, Tobias, 1975). It was noted that damage was not repaired in the postradiation period. This was indicated by the additivity of delivery of divided doses of heavy ions ("Problems of Radiobiology," 1971). The usual sulfhydryl radioprotective agents were not effective against heavy ions (Grigor'yev, Tobias, 1975).

Table 5. Examples of Crepis capillaris rootlets containing cells with multiple chromosomal aberrations

Spacecraft and duration of flight	Variant	Rootlet metaphases analyzed	Aberr. per rootlet	Aberr. per 100 analyzed metaph.	Number of cells with indicated number of lesions per cell				
					1	2	3	4	5
Automatic station, Zond-8 (6 days)	Flight	0	0	0	0	0	0	0	0
	γ-radiation, 3 krad	12	3	25	1	1	0	0	0
	γ-radiation and flight	52	27	52	13	7	0	0	0
Soyuz-9 (18 days)	Flight	10	8	80	5	0	1	0	0
	γ-radiation, 3 krad	34	18	53	1	7	1	0	0
	γ-radiation and flight	57	72	126	20	8	6	2	2
Salyut orbital station (72 days)	Flight	56	4	7	2	1	0	0	0
	γ-radiation, 3 krad	22	30	136	2	3	6	1	0
	γ-radiation and flight	59	110	185	13	11	9	7	4

Note: There were rootlets without aberrant cells in each group.

Studies of the biological effects of heavy ions in space are difficult to pursue, first, because of the difficulty of separating the effects of this factor from those of many others, to which the organism is exposed during a space flight, and second, because of the significant rarity of these particles (Table 1). However, various methodological devices, for example, experiments with a photographic emulsion control of particle hits, yielded results that are not in contradiction to the conclusions made in ground-based experiments.

The capacity of heavy ions to inactivate cells, increase the incidence of spot mutations and chromosomal aberrations is referred to the action of cosmic radiation (Akoyev, Yurov, 1975). However, these effects were unrelated to either duration of flight or dosage of recorded radiation (Glembotskiy, 1970; von Borstel et al., 1968).

Experiments demonstrated mosaicism of the effects observed after space flights, which consisted of the fact that, in the presence of very mild damage to objects in a given variant, there was significant damage to individual specimens or groups of specimens (Table 5) (Khvostova et al., 1963; Vaulina, 1976).

Multiple lesions were demonstrated in the chromosomal system of cells, and it was shown that the number thereof is related to duration of flight (Figure 5) (Vaulina, 1976). Model experiments and flight tests with a photoemulsion control confirmed the assumption that multiple damage to cell chromosomes is induced by heavy ions (Akoyev, Yurov, 1975).

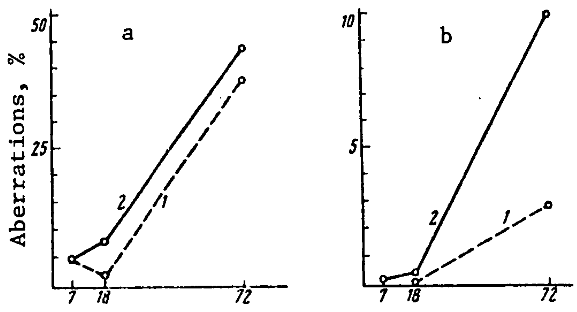


Figure 5. Incidence of cells with single (a) and multiple (b) aberrations as a function of space flight duration

1) control, seeds exposed to 3 krad gamma rays
2) experiment, seeds exposed to space flight and preflight gamma radiation in a dosage of 3 krad

We have already mentioned that cosmic radiation has an effect in conjunction with a number of other flight factors and modifies their effects, or else its effects will be modified by those of other factors. The influence of flight factors on an organism would lead to a complex combination of effects in the same or different directions, and it would result in an effect that would be impossible to attribute to any single factor, even such a potent one as ionizing radiation.

Research on mutagenicity of flight factors is in its most active phase. Development of orbital stations and long-term operation thereof will enable biologists to increase the scope and duration of in-flight experiments, and this in turn will augment the informativeness of the obtained results. All this leads us to expect considerable progress in such research in the very near future.

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CSO: 1866/999

UDC: 613.693:577.462

PROBLEMS OF SPACE BIOLOGY, VOLUME 42: SANITARY-HYGIENIC AND PHYSIOLOGICAL ASPECTS OF MANNED SPACECRAFT

Moscow PROBLEMY KOSMICHESKOY BIOLOGII, TOM 42: SANITARNO-GIGIYENICHESKIYE I FIZIOLOGICHESKIYE ASPEKTY OBITAYEMYKH KOSMICHESKIKH KORABLEY in Russian 1980 (signed to press 4 Sep 80) pp 4-10, 265-267

[Annotation, foreword (by Yu. G. Nefedov and S. N. Zaloguyev), abstracts and table of contents from book "Problems of Space Biology. Volume 42: Sanitary-Hygienic and Physiological Aspects of Manned Spacecraft", edited by Yu. G. Nefedov (editor-in-chief of this volume), Izdatel'stvo "Nauka", 1150 copies, 268 pages]

[Text] One of the main prerequisites for the successful accomplishment of space missions is to create beneficial living conditions in the cabin of a manned space vehicle. This monograph submits a toxicological evaluation of the main sources of pollution of the air environment by impurities and patterns of formation of its aeroion composition, with descriptions of the main changes in man's functional state, discussion of the main microbiological and epidemiological aspects of habitability of pressurized cabins, physiological and hygienic bases for the diet of spacecraft crews.

This monograph is intended for specialists in the field of space biology and medicine.

Foreword

The problem of habitability of manned spacecraft and orbital stations, which refers to the provisions for life and professional work of cosmonauts, consists of a set of physiological and psychological questions, as well as a rather extensive set of sanitary and hygienic conditions to be formed in the pressurized cabin of a space vehicle. The many directions inherent in the issues that make up this problem, many of which have not been resolved, even for man's ordinary living conditions, make it impossible to describe in a single book the entire problem of habitability of spacecraft as a whole.

In this monograph, attention is focused mainly on the current status and prospects of solving some of the sanitary-hygienic and physiological aspects of the problem of habitability of manned space vehicles. The choice of this topic is considered warranted, in view of the fact that these issues are relevant to a spacecraft, orbital station or any confined place, regardless of its purpose.

Special relations are established between man and his environment in a confined place, which are manifested by active formation of the atmosphere by various chemicals that are eliminated in the course of vital functions. We are not referring to fluctuations in composition of the main constituents (oxygen, nitrogen, carbon dioxide), but to pollution of the air environment by various microimpurities.

The extensive group of studies conducted in this direction established that the air exhaled by man is one of the main sources of pollution of the air environment of a sealed place by chemical microimpurities, and the levels thereof are quite variable, depending on a number of conditions: individual distinctions of metabolic processes in the human body, degree of effects of microclimate parameters, composition and caloric value of diet, motor activity and others.

It should be noted that exhaled air is not the only source of pollution of the air environment of pressurized spaces by various chemicals. The products of perspiration and activity of sebaceous glands, as well as intestinal gases can also have a substantial influence on the level of overall pollution and composition of trace impurities in the atmosphere of a pressurized place.

The products of gas emission from polymer items and ornamental-finishing materials used in the interior of a spacecraft may have a marked effect on formation of the inhabited environment. Thus, a study of more than 500 such materials revealed abut 70 various chemical compounds, which were identified and assayed in the products of gas emission. They include highly toxic substances, such as carbon monoxide, epichlorhydrin, hydrogen cyanide and fluoride, etc. It is important to note that the intensity of emission of volatile substances from polymers depends significantly on operating conditions and parameters of the environment. Thus, with change in "specific saturation" by materials in a pressurized cabin and exposure to high temperature, an exponential relationship was established between concentration of discharged substances and these factors.

The effects of toxic chemicals in the atmosphere of a spacecraft on man can be discussed in aspects of acute and chronic toxic effects. A particularly close scrutiny has been given to the possibility of manifestation of a chronic toxic effect of these substances on man. Among them, alcohols of different molecular weight, ethers of these alcohols and acetic acid, ketones, aldehydes, aliphatic hydrocarbons, heterocyclic and inorganic compounds have been found. It is known that, in the case of chronic exposure, alcohols can affect renal and liver function, while hypotension and irritation of the lungs are caused by their ethers. Low toxicity is inherent in aliphatic and aromatic hydrocarbons, but in high concentrations they can elicit certain changes in some internal organs and an anesthetic effect. A diversity of manifestations is observed for the toxic effects of heterocyclic compounds.

The foregoing warrants the belief that it is important to work on development of special methods of investigation and use them to study the dynamics of accumulation of various chemicals in the air of space vehicles. No doubt, the main purpose of such studies should be to assess the toxicological hazard of these substances. However, it is equally important to obtain data on the composition of gaseous chemical impurities responsible for appearance of odors in a spacecraft cabin. When this problem is solved, it will be possible to offer validated recommendations on development of effective filters to remove toxic impurities from air.

Development of principles and criteria for setting air quality standards for future spacecraft, with due consideration of specific requirements of living conditions in a manned space vehicle, as well as the main theses of the Soviet school of hygienists, should also be considered a task for sanitary toxicology.

Aerosols present a great hazard when working in space; the possibility of their penetrating into man's respiratory tract in weightlessness may differ substantially from conditions where there is normal gravity. There are diverse sources of aerosols in a spacecraft; they include man himself, various materials and operating life support systems. When discussing the toxicological hazard of aerosols, it is imperative to consider the fact that they may serve as adsorbents or condensation centers for toxic gaseous impurities. This circumsntance may alleviate penetration into the lower respiratory tract of chemical compounds that are retained in the upper pathways under earth's conditions because of their good solubility in water. The difficulty of this problem as it relates to confined manned systems is that a tendency toward increase in quantity and mean diameter as time passes is inherent in aerosol particles. Nor has the nature of biological effects of ionized aerosols and gases been definitively established, particularly in manned spacecraft cabins. The importance of this problem is attributable to the fact that the constant background of cosmic radiation, the level of which may rise periodically, can lead to an appreciable increase in concentration of aeroions, by about 2-3 times, in the course of a manned space flight, as indicated by estimates. All of the foregoing makes it very important to conduct special studies to resolve the problems that have been raised.

One of the important parts of the habitability problem is to study the mechanisms of onset of diseases caused by representatives of man's automicroflora. This problem is difficult to solve, first of all, because the infectious processes elicited by conditionally pathogenic microorganisms are distinctive, although they retain the main epidemiological patterns.

This problem is of particular significance in sanitary-hygienic support of cosmonauts in a space vehicle operating for a long time, where the intensity of expression of the mechanism of transmission, which is the basis for the process of mutual exchange of man's automicroflora, could increase substantially, as compared to ordinary living conditions. This is indicated by the consistently observed increase in size of microbial sites on the integumental tissues of cosmonauts, as well as increased intensity of elimination of microorganisms from integumental tissues into the environment, which is typical when people spend time in a confined space.

The findings from the above studies, supplemented by determination of the list of microorganisms most frequently involved in causing marked changes in man's automicroflora under such conditions, made it possible to define the most probable pathogens of diseases among the crews of space vehicles on long-term missions.

As we know, the upper respiratory tract, integument and intestine are the main sites of localization of microorganisms in man. Epidemiologically, the upper respiratory tract is the most important, since there is an increase, by about 20-100 times, in intensity of elimination of microorganisms from it when people are in a confined place, as compared to ordinary living conditions. Expressly this circumstance renders the air environment of a sealed place the principal factor in transmission of probable pathogens of diseases.

The role of intestinal microflora in polluting a confined environment is less significant, and apparently is mostly determined by the extent of personal hygiene. However, it is worth stressing that, in addition to medical aspects, there is a hygienic one to the study of human intestinal microflora in a confined environment, which is related to determination of the mechanism of onset of "autoinfectious" diseases, since the composition of this microflora depends, to a large extent, on a number of factors (diet, availability of fluids, etc.), as well as a biological aspect, which is related to the existing conception of the role of intestinal microflora in maintaining homeostasis in the human body.

With reference to the question of onset of diseases of the "cross-infection" type among crew members, we were impressed by the lack of information about conditions, under which the final stage of the mechanism of transmission is expressed, i.e., how microorganisms that have penetrated into the human body as a result of reciprocal exchange "take root." Expressly this problem should be the focus of future microbiological and immunological studies.

We have established that the reciprocal exchange of microorganisms is most often temporary. A real exchange of microorganisms should occur when new organisms become part of the ecological system that is formed when people stay together. There is also information to the effect that the "root-taking" process for microorganisms is determined, to a significant extent, by the state of man's immunological reactivity, his physiological, anatomical distinctions and other circumstances.

All of the foregoing makes it imperative to conduct a wide set of studies in the future on this problem as it relates to medical support of space missions. We believe that investigation of conditions for expression of the "root-taking" process in representatives of the automicroflora of one individual in the organism of another will bring us closer to solving some aspects of the large, general biological problem, the problem of "biological compatibility of people."

It is extremely important, in our opinion, to conduct studies for development of the principles of sanitary and epidemiological support of manned space flights, which also includes the stages of ground-based preparation of crews and space vehicles themselves. The description of the main directions of this area of research is the topic of a separate report; for this reason, we shall discuss only some of the aspects which, in our opinion, are particularly important at this time.

With regard to sanitary and epidemiological support of manned space flights, one of the mandatory conditions in manning crews should be the detection of individuals among them with consistently high initial levels of microorganisms referable to probable pathogens of diseases. If such individuals are found, it is imperative to institute a set of sanitation measures.

It should be noted that the problem of "sanation" of healthy carriers to free them of pathogenic representatives of their automicroflora is still far from being solved in ordinary clinical practice. In spite of this, studies in this direction as they relate to the support of space flights are considered extremely important, and specialists must concentrate on them. One of the rather important aspects of these studies is to develop and assess the ways and means of using effective equipment for monitoring the composition of integumental microflora of cosmonauts spending long periods of time in space vehicles, and the list of these means must include methods of evaluating some properties of microorganisms, for example, their resistance to antibiotics.

The established active role of man's integument in forming the microflora of the spacecraft cabin environment gives us grounds to consider development of personal hygiene measures for cosmonauts as an important and mandatory contribution to epidemic-control support of space flights. In this regard, when planning such studies much attention should be given to the choice and validation, not only of general measures (hygienic shower, washing hands and face, etc.), but special ones aimed at maintaining the integumental microflora within a range that minimizes the possibility of reinfection due to reinoculation of microorganisms. In the latter case, it is desirable to develop both nonspecific (mechanical removal of microorganisms from the integument by using appropriate materials for clothing, bedding and other personal hygiene items) and specific methods (use of various bactericidal agents, selected with due consideration of the distinctions in the change of cosmonauts' automicroflora, as well as those that activate the barrier function of the skin and mucous membranes).

The adversity of conditions, under which people spend time in a confined environment, is aggravated by involvement of operating air conditioning system in preserving and spreading microorganisms. Determination of the fact that certain representatives of the automicroflora are capable of reproducing in condensation moisture, which collects not only in the air-duct system but, as indicated by reports of cosmonauts, on some parts of internal surfaces, warrants consideration of studies of the problem of "bioresistance" of polymers as promising. This problem has been considered heretofore only in the technical aspect, which is of course very important, related to the possibility of equipment malfunction because of reproduction of microorganisms on materials. In solving this problem, it appears to us to be important to pay attention to another aspect as well, to which little attention had been devoted up to this time, i.e., the medical aspect. It is determined by the possibility of involvement in processes of destruction of polymers of conditionally pathogenic microorganisms that are representatives of the human automicroflora, and reproduction of pathogens on polymers before appearance of malfunctions in various equipment sould present a health hazard to cosmonauts in the epidemiological and toxicological aspects.

Development of a proper assortment of foods and proper caloric value of the diet, which is impossible without comprehensive physiological and hygienic studies, is an important part of the work to provide favorable conditions in spacecraft cabins.

In this foreword, it was not our intent to describe even briefly the contents of all of the book's chapters; our main purpose was to give an idea about some of the most pressing problems ensuring from the results of studies submitted in the book, which must be solved in future studies of the problem of habitability of manned space vehicles.

UDC: 612.221.2.014

SOURCES OF POLLUTION OF CABIN ATMOSPHERE BY TRACE IMPURITIES, AND TOXICOLOGICAL EVALUATION THEREOF

[Abstract of article by V. P. Savina and T. I. Kuznetsova]

[Text] The results are submitted of the role of man in polluting the air environment of a confined space with metabolic products. Mean daily levels of elimination of toxic impurities in the air exhaled by man are calculated under normal living conditions; the composition of volatile constituents of perspiration, urine and intestinal gases is given. A study was made of the effect on composition of exhaled air of altered microclimate parameters, different diets, total fast and antiorthostatic [head down] hypokinesia. The obtained results indicate that worsening of living conditions affects the composition of end metabolic products. Fasting, worsening of microclimate with respect to temperature and humidity have the strongest effect. The findings of the studies served as the basis for selecting the main pollutants, the concentration of which is significant in the air environment and which changes under the influence of some factors or other, used to assess the sanitary and hygienic status of the air environment of pressurized places. There are 15 tables, 2 illustrations; bibliography lists 41 items.

UDC: 613.693:615.9

HYGIENE AND TOXICOLOGY OF NONMETAL MATERIALS

[Abstract of article by G. I. Solomin]

[Text] This article deals with questions of safe use of polymers for equipment in manned compartments of space vehicles. Experimental data are submitted on the effects of space flight factors on the process of gassing from polymers; the influence of trace impurities on formation of the gas environment of confined places is demonstrated. Data are submitted for scientific validation of a system of hygienic monitoring of safe use of materials at different stages of construction of space vehicles. A system is offered for setting up experiments, scope of studies and main directions of work. There is 1 table; bibliography lists 34 items.

UDC: 612.014.464:613.693

HYGIENIC SIGNIFICANCE OF IONIZATION OF THE ATMOSPHERE OF MANNED SPACECRAFT CABINS

[Abstract of article by B. V. Anisimov]

[Text] It was shown, on the basis of analysis of the literature and the author's own experimental findings, that ionization of the atmosphere during space flights would have a substantial effect on all functional systems of man. It is concluded that it is imperative to regulate both the concentration of light aeroions and coefficient of unipolarity in order to assure a biologically ideal atmosphere in pressurized cabins. Bibliography lists 37 items.

UDC: 613-036.22;576.8;629.7.014.18

SANITARY-MICROBIOLOGICAL AND EPIDEMIOLOGICAL ASPECTS OF HABITABILITY

[Abstract of article by S. N. Zaloguyev, A. N. Viktorov and N. D. Startseva]

[Text] The probability of appearance in cosmonauts of diseases, the pathogens of which will be mainly representatives of their own microflora, makes it necessary to conduct special studies to determine the distinctions of expression of the mechanism of transmission of microorganisms under these specific living conditions. It was established that unfavorable changes occur in total amount of microorganisms on the integumental tissues of cosmonauts, referable to an increase in staphylococci, hemolytic streptococci and representatives of Gram-negative bacillary and cocal flora, as well as yeast-like fungal flora. A comprehensive study of the composition of staphylococcal flora of cosmonauts revealed that there is periodic increase in number of staphylococci on their integumental tissue with pathogenic traits and resistance to many antibiotics. The presence among cosmonauts of a rather large number of carriers of pathogenic staphylococci and other microorganisms, associated with increased intensity of eliminating these microorganisms into the environment, is indicative of man's increasing role as the probable source of infection under these conditions. The air environment is the principal factor in transmission of microorganisms in spacecraft cabins, and the internal surfaces are actively involved as mode of transmission. The obtained data, as well as information about the distinctions of formation of bacterial aerosol in pressurized cabins of spacecraft, warrant the belief that there can be faster expression of the mechanism of transmission of microorganisms under these living conditions than on earth. There are 18 tables; bibliography lists 110 items.

UDC: 612.338.31

MICROECOLOGY OF THE INTESTINE UNDER EXTREME CONDITIONS

[Abstract of article by V. M. Shilov and N. N. Liz'ko]

[Text] This article deals with current conceptions of the composition of intestinal microflora and its role in vital functions of the body. Along with the positive role, the authors also call attention to the deleterious effects of microflora on the macroorganism and potential pathogenicity of a number of representatives of man's obligate microflora. This work sums up the many years of studies pursued by the authors on intestinal microflora, both of individuals isolated in a confined place and cosmonauts, before and after participating in space missions of different duration. Methods of normalizing the intestinal microflora of cosmonauts during space flights are discussed in connection with development of dysbacteriosis under the influence of extreme factors on the body. There are 1 table, 11 illustrations; bibliography lists 61 items.

UDC: 613.693

EVALUATION OF MAN'S FUNCTIONAL CAPACITIES UNDER EXTREME LIVING CONDITIONS

[Abstract of article by G. A. Manovtsev and V. V. Zhuravlev]

[Text] This section deals with evaluation of different functions of the human body under conditions of isolation in a pressurized compartment of limited size for several weeks to 1 year. There is discussion of the results of studies of functional state of the cardiovascular system, external respiration, neuromuscular activity, acid-base equilibrium and heat regulation in man. The results of experimental studies are described with reference to optimum living conditions for man and with significant deviation of different parameters of the habitat from optimum levels (altered gas environment in a pressurized place and worsening of microclimate conditions). Information is furnished on functional state of different physiological systems of man as a function of parameters of environment in a pressurized compartment. There are 3 illustrations; bibliography lists 46 items.

UDC: 613.693:612.017.1

IMMUNOLOGICAL REACTIVITY OF THE BODY DURING STAYS IN CONFINED QUARTERS

[Abstract of article by I. V. Konstantinova and Ye. N. Antropova]

[Text] There is discussion of the distinctions of man's immunoreactivity while living in a sealed place with maintenance of the main parameters of the microclimate within the range of the hygienic standard, as well as with different degrees of pollution of the air environment by trace impurities of a biological and chemical nature. Data are submitted from a study of the effects of factors involved in space flights of different duration on the cosmonauts' immunity system. It was shown that changes in parameters of the microclimate elicit changes in man's immunoreactivity. Long-term space missions (30-140 days) elicit a number of functional changes in the immunological system of cosmonauts, leading to diminished function of T lymphocytes, change in levels of different subpopulations of immunocompetent lymphocytes and immunoglobulins of the G and A classes, appearance of sensitization to bacterial allergens and activation of signs of autoimmune processes. Brief space flights (6-8 days) do not have an appreciable effect on immunological reactivity of man. There are 1 table, 3 illustrations; bibliography lists 22 items.

UDC: 613.693:612.39

PRINCIPLES INVOLVED IN CREATING FOOD ELEMENTS IN LIFE SUPPORT SYSTEMS FOR SPACECRAFT CREWS

[Abstract of article by V. P. Bychkov]

[Text] This article submits data on principles for furnishing the food elements of life support systems for spacecraft crews as related to duration of missions. There is a summary of experimental data on food supplies for manned space flights performed in the USSR and the United States. In addition, there is discussion of data pertaining to the distinctions of metabolic processes in man during space flights and development of foods for future space vehicles. There are 8 tables; bibliography lists 205 items.

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CARDIOVASCULAR CONDITIONING FOR COSMONAUTS

Minsk PERIFERICHESKIYE "SERDTSA" CHELOVEKA in Russian 1980 pp 64-67

[Section from book "Peripheral 'Hearts' of Man", by N. I. Arinchin, Institute of Physiology, Belorussian Academy of Sciences, Izdatel'stvo "Nauka i tekhnika", 80 pages]

[Text] In the opinion of S. P. Korolev, any essentially healthy person who can endure the accelerations during lift-off and deboosting [deceleration] of a descending spacecraft can fly in space. And the possibility of making such voyages is increasing.

But, during space flights, particularly long-term ones, the cosmonaut is exposed to devastating hypokinesia and weightlessness, as we know. Since orbital spacecraft fly at altitudes of 200-300 km, i.e., in the top layers of the atmosphere, they gradually "fall" to earth, their orbit changes and cosmonauts experience weightlessness under the influence of braking created by air and earth's gravity. It induces changes in cosmonauts referable to bones, muscles, the vestibular system and other organs, particularly those of the cardiovascular system.

On earth, in erect position, blood of venous vessels so to speak "falls" freely from the top of the human body by virtue of its own weight down toward the heart. It has difficulty in rising from the lower limbs, and for this reason it accumulates in venous and capillary vessels, the tonus of which is considerably higher than in other parts of the body. In weightlessness, however, there is less blood in the vessels of the lower extremities, since it flows to the top of the body, overfilling vessels of the lungs and brain, which creates the sensation of heaviness, headache, etc.; efficiency of cosmonauts diminishes. During long-term flights, there is adaptation of the body and its cardiovascular system to weightlessness, but upon returning to earth the cosmonauts are again "in the embrace" of gravity, and it has been found even more difficult to endure it than to become accustomed to weightlessness. In order to improve the reliability of circulation in weightlessness and to prepare cosmonauts for their return to earth, there is a special compartment on orbital stations for diverse biomedical tests and training [conditioning]. The cosmonauts use a vacuum chamber, which creates negative pressure in the lower part of the body, as a result of which the veins and capillaries of the lower limbs dilate and are filled with blood which flows from the head. This improves cerebral circulation, and it also conditions the heart and vessels to the impending return to earth, when gravity will again attract blood to the vessels of the lower extremities.

There are bicycle ergometers, treadmills, special G suits, expanders, etc., aboard spacecraft. Physical exercise in a specific volume, of specific duration and intensity is recommended for cosmonauts up to the point when they experience some fatigue which, in the opinion of Academician O. G. Gazenko, is beneficial. For example, at his recommendation, V. I. Sevast'yanov began to take 120, instead of 100, steps per minute on the treadmill. Upon returning to earth, V. I. Sevast'yanov crawled out of the landed craft and, having immediately taken a few steps, began to prance: "Look, I can walk. This is a miracle!" The same miracle happened after the 140-day record flight of Vladimir Kovalenko and Aleksandr Ivanchenkov.

Academician O. G. Gazenko and his team of coworkers, were awarded the USSR State Prize for developing the set of methods for preparing cosmonauts for long-term flights. O. G. Gazenko and Ye. B. Shul'zhenko believe that venous pumps are involved in the circulation of cosmonauts. In addition to them, stimulation of suction-pumping micropump activity of skeletal muscles is also important, since it is controllable by means of voluntary regulation by each cosmonaut. Skeletal muscles, which constitute 40-50% of body mass, pull more blood when they are functional than at rest, and consequently less amounts thereof flow to the brain in weightlessness. This is instrumental in providing for high efficiency [work fitness] of cosmonauts engaged in geophysical, astronomical, meteorological, bio-medical and many other studies. For this reason, all cosmonauts are highly trained athletes to assure their reliability. A certain time is reserved for different forms of sports in their multifaceted training program.

A. A. Gubarev and G. M. Grechko trained for their flight for about 4 years. A. S. Yeliseyev, Ye. V. Khrunov and others experienced weightlessness aboard a laboratory aircraft. G. T. Beregovoy believes that sports are to be credited for his 4-day flight aboard the Soyuz-3 spacecraft. Sports make it possible for a person 40-50 years of age to become a cosmonaut and perform work related to flight for a rather long time. For this reason, in the village of Zvezdnyy, sports training of cosmonauts is being conducted so thoroughly and systematically. For this purpose, there are a stadium, gyms and playing fields, swimming pool and ski centers. A. G. Nikolayev said that, during the flight with V. I. Sevast'yanov, without any special physical training it is unlikely that they would have returned to earth without experiencing some pain, since the unconditioned heart would not have coped with the effect of gravity.

A. A. Leonov, pilot-cosmonaut of the USSR, chairman of the All-Union Council for GTO, is handing over to our country's entire population the knowhow gained in physical training of cosmonauts.

On 17 December 1978, the head of the Center for Cosmonaut Training imeni Yu. A. Gagarin, G. T. Beregovoy, pilot-cosmonaut of the USSR, made a request on the pages of the newspaper SOVETSKIY SPORT that suggestions be offered for new types of sports activities for cosmonauts aboard space stations. Such suggestions must and will be made, with due consideration of the fact that skeletal muscles also have their own independent micropumping capacity, which man can control, not only on earth but in space.

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CSO: 1866/999

PROBLEM OF ADAPTATION IN SPACE BIOLOGY AND MEDICINE

Moscow OSVOYENIYE KOSMOSA I VZAIMOSVYAZ' NAUK. TRUDY CHETYRNADTSATYKH CHTENIY, POSVYASHCHENNYKH RAZRABOTKE NAUCHNOGO NASLEDIYA I RAZVITIYA IDEY K. E. TSIOLKOVSKOGO, (KALUGA 11-14 SENTYABRYA 1979 G.) SEKTSIYA: "K. E. TSIOLKOVSKIY I FILOSOFSKIYE PROBLEMY OSVOYENIYA KOSMOSA" in Russian 1980 pp 80-90

[Article by A. V. Korobkov, F. P. Kosmolinskiy and I. M. Khazen from book "Exploration of Space and Correlation Between Sciences. Proceedings of 14th Lecture Series Dedicated to Development of the Scientific Heritage and Ideas of K. E. Tsiolkovskiy (Kaluga 11-14 September 1979). Section of "K. E. Tsiolkovskiy and Philosophical Problems of Space Exploration", edited by Prof A. D. Ursul, doctor of philosophical sciences, Ye. T. Faddeyev, candidate of philosophical sciences and Yu. A. Shkolenko, candidate of philosophical sciences, Commission for Development of the Scientific Heritage of K. E. Tsiolkovskiy of the USSR Academy of Sciences]

[Text] It is unlikely that we could find a more important problem of space biology and medicine than the problem of man's adaptation to life and work under extra-terrestrial conditions, i.e., living conditions that are known to be unusual for him. So that it is quite legitimate for K. E. Tsiolkovskiy to pay such close attention to problems of altering man and his possible evolution in creating and developing "ethereal cities" of the future [1-3]. Tsiolkovskiy was optimistic about man living in space for a long time. He advanced a thought which is very important and promising to research, that man would gradually change in the "ether" and the danger of "emptiness" and other adverse influences related to being in space would not be so significant and devastating to him [2, leaf 6].

Man's adaptation to life in space implies both the creation of a comfortable artificial exogenous environment, which would not elicit significant changes in man (passive adaptation) and psychophysiological and intellectual adaptation of man, particularly to the space factors to which it is difficult to adapt by means of technical devices alone and there are significant adaptive changes in the body (active adaptation). This conception of man's adaptation has something in common with Tsiolkovskiy's views of the possibility of man's gradual (over a period of centuries) adaptation to "ethereal" conditions: "At the present time, the progressive strata of mankind are striving more and more to place their life into an artificial framework, and is this not what progress means?.... In the ether this artificiality will merely reach its extreme, but man will be under the most beneficial conditions. As the centuries pass, the new conditions will also create a new breed of beings, and the artificiality around them will be attenuated and, perhaps, gradually taper off. Would not the conquest of ethereal space follow the conquest of air: will the air-bound being change into an ethereal one?" [3, p 137].

This quotation is indicative of the profound evolutionary approach to the problem of emergence of a new type of human beings adapted to life in a space environment. We are not dealing here with the possibility of life for modern man in space, but with the basic philosophical and biological approach to the question of possibility of creating a "new breed of beings" as a result of evolution of the human population. Tsiolkovskiy views altered living conditions as the cause of such evolution. The problem of social and biological adaptation of man to life in space, as the important basis for creating a space civilization, imparted with new properties that permit active adaptation to extraterrestrial living conditions, is considered by Tsiolkovskiy from populocentric positions.

As we consider the emerging routes for solving the problem that was touched upon, it is imperative to avoid absolutization of the knowledge we gained at different important stages of exploration of space, and to interpret them as the means of coming gradually closer to understanding the deeper substance of the processes studied.

At the same time, we must take into consideration the need for an utterly new level of solutions to basic and applied problems. At the present time, it is characterized by a change in rating of values in orientation, science and "industrialization" of a number of means of solving experimental problems. More and more, theoretical knowledge is gaining features that are essentially similar to a biotechnological design.

For example, in developing the ways and means of compensating for the effects of weightlessness and other factors of space flights, on the basis of experimental work done in 1954 [4], we arrived at the conclusion that nothing can replace skeletomuscular activity in flight, that it must be used as the most important factor in the life of cosmonauts, in combination with positive emotions, nutrition and controlling [regulatory] pharmacology. The obtained data were indicative of the importance of specific functional conditioning related to the function of the vestibular system, cerebellum, etc. Concurrently, there was formulation of some of the distinctions of preflight, in-flight and postflight physical training and exercise. In the first programs of physical training, broad use was made of data indicative of the required energy level of muscular contraction, topography of function of different muscle groups and other data for the practical solution of this problem. It was stressed that physical and other loads must be optimized [5]. Subsequently, theory and methods of using local negative pressure (LNP) and lower body negative pressure (LBNP) began to be used, and this aided in elaborating the exercise regimen for cosmonauts at all stages of flight, the Chibis device and Penguin suit.

On the whole, the fundamental conception formulated in the course of this work, to the effect that active muscular contraction based on feedback is a factor of paramount importance to compensate for the absence of effects of gravity, was the basis for a step forward, both with respect to solving problems of compensation for the effects of weightlessness and adaptation to it. However, this is only the beginning, and it is imperative to advance over the ways that were opened toward solving new qualitative aspects of the problem.

The most important and basically new living factors in space are weightlessness and related hypodynamia, as well as cosmic radiation, the hazard of which cannot be underestimated. In this regard, a question arises: are the genetic system and functional status of modern man reliable, and what are its capacities for variability for the purpose of adaptive changes and creation of a new level of dynamic equilibrium of homeostasis with the habitat? Is it possible for there to be stable adaptation of different generations of modern man to living and working conditions in space? To what extent is Tsiolkovskiy's opinion of the possibility of creating a "new breed of beings" in ethereal space valid?

Marxist-Leninist theory considers the social essence of man in dialectical unity with the distinctions of his vital functions (biological characteristics) as a component of nature. In principle, it does not restrict the possibility of man's development as a personality and biological processes in his body. For this reason there are no grounds to reject the possibility of formation of a new human population in the space environment.

Consideration of man's evolution from the populocentric point of view over many generations assures the fullest disclosure of the mechanisms of man's adaptation. We define physiological adaptation as a process that leads to a new stable level of cell and tissue, organ and system function, as well as mechanisms of control, which makes it possible, on the basis of a balance between expenditure and restoration of the body's resources, for man's vital functions to take place and for him to work under new living conditions, and for a healthy progeny to develop. At the same time, this process is very variable on the population level. The role of the social and biological environment is of first and foremost significance in the genesis of man's adaptation. Social programs of man's development provide for transmission of his knowhow to generations through processes of rearing, training and education. Thereby, man, who is the carrier of the social program, implements evolution of social forms of movement of matter by means of refinement of education and labor [7, 8].

On earth, biological evolution of man is very limited in view of the relatively standard living conditions. The obtained data indicate that 4-5 generations must live in the mountains to develop a mountain-dwelling aborigene. But the question of whether the reserves of the human body have been exhausted for deeper evolution under new space conditions (the possibility of which Tsiolkovskiy does not question) has not been definitively answered.

Evidently, in the history of the future human population developing in space, which is the basis of space civilization, social programs of its development will be of prime significance in the entire scope of life, including deployment of functional programs and in connection with the need to develop the ways and means of creating conditions that will induce a change in genetic programs, directed at formation of new physiological and psychological properties in space organisms. The possibility cannot be ruled out that "genetic engineering" procedures (although this, unquestionably, already generates and will generate a number of biological-technical and sociological-ethical problems) will also be used to form biological and functional adaptation programs in the interests of conquering space. Under the influence of living conditions in space, there will also be a change in psychophysiological interaction between man and the environment, the effects of which are related both to new space factors and separation from terrestrial living conditions. Dialectical correlation between structure and function, expenditure and recovery of energy, structural and other reserves of the body will conform with the new dynamics of existence, intended for many generations.

Man's consciousness will be of enormous significance in this change (manifestations thereof such as knowledge, motivation, needs, purposefulness, etc.), since he will continue to live in a social environment and act in the sphere of the social form of movement of matter. In spite of the increasing role of the genetic program (particularly during the period related to change in biological and psychological status of the organism in accordance with space conditions), the social program, which is profoundly linked with various forms of labor, will retain its prime significance.

The role of level of knowledge and intelligence in the conquest of space is confirmed by the current practice of exploration of near space. This explains, in particular (along with the active medical and technical steps taken to affect the psychophysiological status of cosmonauts), the fact that, in spite of the signification extension of time space crews spend on orbital stations, the health status and efficiency of cosmonauts are not worsening. Prior experience in manned space flights has its effect, there is less emotional and mental tension, motivational and competitive stimuli are triggered, there is more confidence in the exceptional importance of space research involving man, and there is an increase in the intellectual potential of crews (including the ground-based flight support service) and their experience in working in a specified, strictly circumscribed and self-disciplined mode.

In his works, Tsiolkovskiy also analyzed the origin of life, from the initial atomic level to formation and development of living structures, from consideration of the principles of structure and properties of animals, as related to their size and existing gravity, to preservation of vigor, fitness and active longevity [9-11]. It is quite possible that Tsiolkovskiy was aware of the thesis expounded by I. M. Sechenov as far back as 1863, which stressed the significance of the molecular level to vital functions [12].

In studies on problems of adaptation, exceptional importance is attributed to various biological levels of integration of functions, their regulation and compensation. Thus, A. M. Chernykh [13] discusses 10 levels of self-regulation of the organism. The highest cortical level includes integration of all other levels and reflects the multiorganic and intersystem relations. Special significance is attributed to the biosocial level, which interacts with environmental factors [14, 15].

Starting with the works of I. M. Sechenov, N. Ye. Vvedenskiy, I. P. Pavlov and A. A. Ukhtomskiy, the teaching on adaptation began to stand on solid scientific positions and deal with all adaptive reactions of the body as a dynamic phasic process under the direct control of the central nervous system.

We believe that utmost information can be obtained with consideration of the organism's responses to a perceived and unperceived interacting stimulus from the standpoint of theories of Russian classics in the natural sciences.

This direction was successfully developed in the studies of I. P. Razenkov [16], who also singled out three phases of adaptation (and a fourth, intermediate one). I. M. Khazen, who worked on this problem, singled out five phases [17]. F. P. Kosmolinskiy found four [18]. The research of N. V. Lazarev on the state of nonspecific heightened resistance of the organism (SNHR), developing under the influence of a special group of substances (adaptogens), is important [19]. On the basis of teaching on SNHR, there was development of a classification of adaptive states by L. Kh. Garkavi, Ye. B. Kvakina and M. A. Ukolova [20]: conditioning reaction (to mild stimuli), activation reaction (to moderate stimuli) and tension (stress) reaction to strong stimuli. A. V. Korobkov [5] mentioned five different phases of adaptation and preparedness of an organism for adaptation as a most important preliminary stage, stressing the role of motor activity to nonspecific resistance at all phases of adaptation. The teaching on phasic states of the organism, which was developed by Soviet scientists, is more comprehensive and a scientifically more finished entity than Selye's stress theory, which reflects only part of the hormonal reactions in the hypophysis-adrenal system (which were, unquestionably, submitted to in-depth investigation by Selye and his school).

Problems related to human ecology are of special importance to work on the problem of development of a space civilization. Scientific-technological and economic problems of the "space station (city) -- human population -- space" system are acquiring special and specific significance. In such a system work and other loads should be such as to permit removal of fatigue before the next work cycle and they should not affect health. This should be implemented by the industry of re-creating health, directed at preservation and reproduction of manpower resources in space civilization.

Longevity has become a necessity dictated by the tasks of space exploration, while space provides new impetus and means of achieving this. For this reason, problems of life and death in space require special investigation.

The concept of health of an individual man on earth, as well as in space, cannot be extended to the population health level. This is a different biosocial category. Man's health is determined by his activity and life span. But population health is also characterized by social times, effectiveness of social production, etc., which determine the optimum development of a population. It is imperative to investigate the very concept of population and criteria that characterize it, as well as sociodemographic processes in a space civilization on the basis of integration of data in hygiene, psychology, physiology, biorhythmology, therapeutic medicine and others, with due consideration of the new level and nature of life support systems, mental and physical activity during life in space.

Thus, socio-anthropo-ecological studies should alter the routes of development of anthropology that were formed on earth. We must continue the development of the conceptions of V. I. Vernadskiy concerning the sphere of intelligence--noosphere, as related to a space civilization [21].

The role of man, with his consciousness and activities in a space civilization, will undergo exceptional increase. He will create a specific, continuously controlled scientific and technological environment as the basic environment of his existence. This environment cannot be equated with natural environmental factors. Scientific-technological factors and substances are natural in origin. But man organizes them and imparts properties to them in such a way that does not exist in nature. At the same time, technological systems combine the laws of nature (natural science) and social development. Technology is governed by its own laws, which are formed under the influence of both natural and social factors. In a space civilization, complex organization and automation of states, as well as development of a scientific-technological environment on the basis of interaction between social, natural and engineering sciences, will reach a new level, higher than on earth, without which life itself would be impossible in space. This creates additional conditions and stimuli for disclosure of the capabilities of the human personality.

All of the foregoing is indicative of the need to make a special study of the problem of man and human population in a scientific-technological space environment (study of capacities of the human body for change in nature of energy exchange with the environment, etc.). No doubt, in the philosophical respect, the works of the classics in Marxism-Leninism, as well as Tsiolkovskiy and Vernadskiy [21-23], are very important to predicting man's life in space. At the same time, when discussing the problem of man's adaptation from the populocentric aspects of evolution, one cannot equate variability and adaptability [24].

The life of human society will develop on the basis of processes of evolution and adaptogenesis, both on earth and under extraterrestrial conditions, and the optimism of Tsiolkovskiy, who maintained that "... there is no end ... to the refinement of mankind. Its progress is perpetual" [23, p 139], is fully warranted. In the opinion of Ye. T. Faddeyev, "the ideas of K. E. Tsiolkovskiy concerning the perpetual development of intelligent social beings, the possibility of such development for each civilization, including our terrestrial mankind," are of great philosophical importance [24, pp 29-30].

In conclusion, we consider it mandatory to stress that all space problems were born on earth, and they will continue to generate and be refined in the foreseeable future, in many respects, on earth. For this reason, the study of ecology of terrestrial human populations, qualitative aspects of coordination of movement, metabolism and energy in the human body, as it interacts with the overall natural environment and the environment created by the course of scientific and technological process (civilization) will be the basis for developing the entire system of a space civilization.

Investigation of the reserves of the human body for the continued evolution thereof, as well as the principal routes, dynamics and structure of this process, should be considered of special importance.

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10,657
CSO: 1866/999

SPACE ENGINEERING

UDC 629.78.002.2(075.8)

TECHNOLOGY OF ASSEMBLY, INSTALLATION AND REPAIR WORK IN SPACE

Moscow OSNOVY KOSMICHESKOY TEKHNOLOGII in Russian 1980 (signed to press 26 May 80) pp 100-115

[Part 3, Chapter 1, Sections 1.1-1.3 from book "Principles of Space Technology", by Ivan Timofeyevich Belyakov and Yuriy Dmitriyevich Borisov, Izdatel'stvo "Mashinostroyeniye", 2,000 copies, 185 pages]

[Excerpt] Part 3. Technology of Assembly, Installation and Repair Work in Space

The development of rocket and space technology is following the path of the creation of ever heavier, more complicated and larger objects in space, including the space technological complexes that will be built in the near future. In order to build and support the extended functioning of space systems, we now need to be able to carry out in space the technological processes involved in installing, repairing, monitoring and testing equipment and maintaining an object in space and its various systems.

Chapter 1. Assembly of Objects

At the present time we are witnessing the construction of large orbital complexes of the "Soyuz"-"Salyut"-"Progress" type. At the same time, however, plans for large, multipurpose, long-lived orbital base stations are also being developed. An example of this is the American Macdonnell-Douglas Company's plan for a base station for 50 people that weighs 450 t and has a useful volume of 2,700 m^3 and a central unit that is 114 m long. In order to create artificial gravity of up to $1g_0$, it is specified that the station will rotate at a speed of 3.5 r/min relative to the central unit's longitudinal axis. The proposed power supply is a nuclear power plant.

As a result of the power shortage that we are experiencing even now, plans for a photoelectric solar power station in space are beginning to be developed. The dimensions of this station are truly fantastic: it will be about 10-12 km long and 5 km wide. With a solar battery about 4 x 5 km in size, a parabolic microwave antenna for transmitting energy in the ultrasonic band from the ultrahigh-frequency generator to Earth, and a total mass of about 20,000 t, the station will have an output power of 5-10 GW. The design, engineering and control problems involved in the creation of such a station are truly huge. It is necessary to solve problems about the choice of the structural power system for the station's basic assemblies; the choice of materials that will provide prolonged strength under the conditions encountered in space; the prevention of the appearance of an inadmissibly high space electrostatic charge on the station because of the effect of the cosmic plasma; the delivery of the units forming the station into orbit, their assembly, the maintenance of the station and so on.

Calculations show that as the dimensions of objects delivered into orbit and, consequently, the energy expenditures for a given flight increase, there is also an increase in the ratio of the rocket system's liftoff mass to the weight of the useful load. This makes it necessary to build launch vehicles of gigantic size and power and makes the development and operation of launch complexes more expensive. Therefore, the assembly in orbit of the individual elements of spacecraft, as well as the servicing of such craft in orbit, will make it possible to eliminate this unjustified increase in the power of launch vehicles and will give us the ability to build space rocket systems tailored to given problems at less cost. It is also possible to demonstrate the feasibility of using a number of assembly methods in space: docking assembly of objects in space from separate units delivered from Earth; assembly of objects from transformable parts; assembly of large areal structures by cosmonauts in open space.

All of these assembly methods are dictated by the necessity of reducing energy expenditures for the delivery of large objects into orbit.

The development of new technological assembly processes and the determination of the structural engineering requirements for dockable assemblies and the necessary technological equipment are both necessary prerequisites for the creation of long-lived orbital stations and other objects in space.

The planning of technological operations for the conditions encountered in space involves a complex of technical, technological, design and ergonomic problems.

As the basic features of the planning of technological operations for space (after demonstrating their effectiveness or substantiating the need for them), we can distinguish the following:

careful development and perfection of operations on the ground but under conditions as close to those encountered in space as possible;

evaluation of the functional capabilities for the cosmonaut-operator's actions under space conditions with respect to specific operations;

creation of a theoretical (mathematical) model of a process on which a technological operation is based, for the purpose of obtaining information about the process's basic parameters and their interrelationship, as well as optimization of a process's basic parameters for the purpose of insuring the required assembly work quality;

creation of working facilities and accommodations for the operator-technologist;

guaranteeing the safety of a cosmonaut-technologist while working.

Let us move on to a discussion of methods for assembling space objects.

1.1. Docking-Assembly of Space Stations

At the present time we are already carrying out the docking-assembly of space stations in orbit, using independent units delivered from Earth that have their own propulsion systems; an example of this is the assembly of the "Soyuz"-"Salyut"-

"Progress" complexes. We can expect the development of this assembly method on the basis of the creation of special technological docking assemblies with a simplified design. These general-purpose technological assemblies can be used repeatedly for the direct docking of units delivered into orbit and the joining of these units in the position needed for the realization of a technological process, after which the docking assembly can be dismantled for the purpose of using it again to assemble other units.

Docking-assembly of space stations in orbit can be regarded as the first stage in the development of assembly work in space. At the present time, docking-assembly of space stations is the most developed method of assembly in space.

Docking-assembly can be carried out either automatically or manually (by a cosmonaut). The possibilities of docking-assembly are determined by the degree of perfection of the facilities used to search for the objects to be put together, as well as the maneuvering, approach and docking equipment, the perfection of the docking assemblies' design and--in the case of the use of semiautomatic docking--the cosmonaut's skill. Despite the huge complexities that must be dealt with when working out docking-assembly operations in space, this type of assembly should be regarded as the method of assembling space objects that is most accessible at the present time. Docking-assembly can, obviously, be only the first stage in the technological process of the assembly of large orbital stations in orbit. Actually, after the docking (mooring) of units to be assembled in space, the technological process of assembly can carried out immediately. In this case it is possible to introduce purely technological requirements for assemblies (units) that are to be assembled by docking-assembly and the technological processes that are being developed

This type of requirement can include the following.

1. Units delivered for docking-assembly must be assembled on Earth in their maximally finished form. (In particular, in view of the obvious difficulties involved in carrying them out in space, coating application processes must be implemented under terrestrial conditions.)

2. The units' docking assemblies must be completely interchangeable.

3. If it is necessary to make a permanent connection at the joint after docking-assembly, the docking assembly itself must insure reliable engagement of the units (mechanical, electromagnetic and other types) throughout the entire period that the work is being done. In connection with this, there must not be any adjustment work that has to be done when the permanent connection is being made and the connecting processes must be maximally automated.

4. The design of the docking points must make it possible to perform repair and restoration work in the case of disruption of a joint's normal functioning (the airtightness is lost, for example) without undocking of the units involved (particularly those joined by permanent connections).

5. Angular compensation can be provided during the assembly of units either by the design of the docking assembly or during the connecting process, with the help of special correcting devices and reference points on the surfaces of the units being assembled.

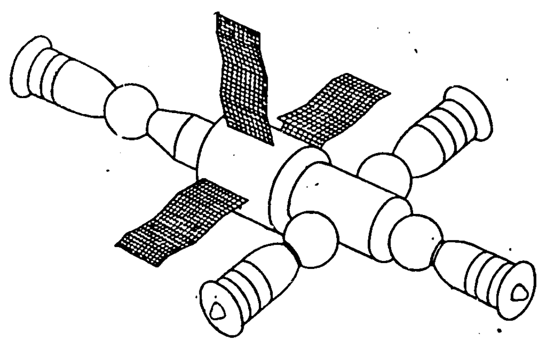

Figure 3.1. Long-term orbital station assembled from independent units.

By using the docking-assembly method, it is possible to assemble rather large space stations by adding additional units to the basic one (Figure 3.1).

Let us examine several details of the process of the docking-assembly of space stations from independent units. Each unit of such a space station must be delivered into orbit by a separate launch vehicle. In order to solve this problem, methods and systems must be developed whereby two ships inserted into nearby orbits can find each other, maneuver, approach, moor and dock, either completely automatically or with the participation of a cosmonaut.

The automatic docking (and then undocking) of unmanned spacecraft was first accomplished on 30 October 1967, during the orbital flight of the Soviet "Kosmos-186" and "Kosmos-188" satellites. In connection with this, one satellite was "active" and the other was "passive." The first satellite carried out such complicated functions as searching for the other one in space, detecting it, approaching it and mooring; the "passive" satellite was simpler: it was oriented in space in a certain manner and served as a beacon for the active satellite. In order to be able to move in space, each satellite had a propulsion system that could be used repeatedly for orbital correction and rendezvousing. For orientation and stabilization, as well as for precise regulation of the mooring process during docking, both satellites had systems of low-thrust reaction engines. The docking assemblies insured retraction and provided a reliable mechanical connection between the two satellites.

Docking-assembly is preceded by the following operations:

1. Launch and injection into orbit of the passive object (target), which does not maneuver in orbit (a situation where both spacecraft maneuver is also possible).

2. Launch and injection of the maneuverable object into the meeting zone.

3. Search and location (capture) of the target.

4. Rendezvous and mooring.

The docking stage begins at the moment of first contact of the docking mechanisms and ends with the final mechanical and electrical connnection of the craft that are docking.

The docking of orbital objects is a critical operation, since the docking objects enter direct physical interaction with each other (in the general case, with a nonzero relative velocity and a different relative orientation). The docking process depends to a large degree on the initial conditions of the docking stage and the docking mechanisms' characteristics.

On the basis of experimental data, the following initial docking condition values are the most satisfactory: relative mooring velocity--0.03-0.075 m/s; lateral displacement with respect to the axis--±0.5 m; angular misalignment (with respect to all axes)--±5°.

Let us enumerate the docking mechanisms' basic assignments:
reduce the difference in the docking objects' velocities to zero; that is, to act as a shock absorber by receiving and scattering the kinetic energy;
after first contact, to provide a mechanical connection between the craft so as to prevent their rebounding from each other after contact;
compensate for the mutual misalignment of the craft's axes that can occur by the moment of first contact;
insure the matching of the alignment of the axes of both craft and triggering of the locks after first contact without use of the propulsion systems;
after triggering of the basic locks, provide sufficient rigidity of the connection and the transmission of loads through the locks when there is joint maneuvering of both craft;
provide an airtight connection when necessary;
make it possible for the craft to disengage immediately when necessary;
provide repulsive forces during disengagement;
be ready for repeated use immediately after disengagement;
make it possible to transmit electrical signals, transfer fuel and cargo and trade crews between the two craft;
have adequate reliability and little mass.

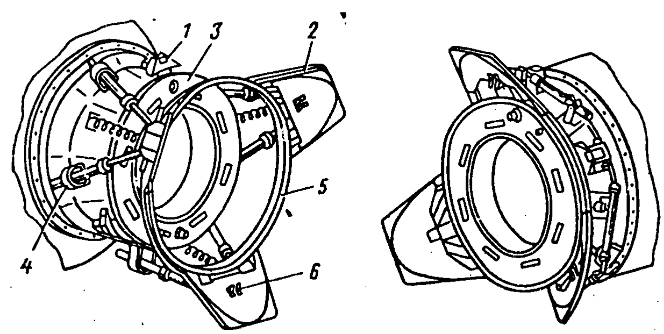

Figure 3.2. Androgynous docking assembly in the "Soyuz"-"Apollo" system: 1. lock on ship's hull; 2. guide on lateral face of a lobe; 3. end ring with eight locks; 4. power cylinders; 5. guide ring; 6. lock on lobe.

Figure 3.2 depicts the androgynous-type docking assembly used to dock the "Soyuz" and "Apollo" ships.

For purposes of simplifying the search and guidance systems and the docking-assembly of units, it is possible to use special towing and manipulating devices located on the basic unit of the space station being assembled. In this case the basic unit can be (for example) equipped with a net, with the help of which it captures the structural units sent after it from Earth that need to be combined with the basic unit (Figure 3.3a, b). By unwinding, the braking cable slows down the captured structural unit and then pulls the units together (Figure 3.3c, d). With the help of a manipulator on the basic unit, a docking assembly of simplified design is oriented correctly, the captured structural unit is brought up to the

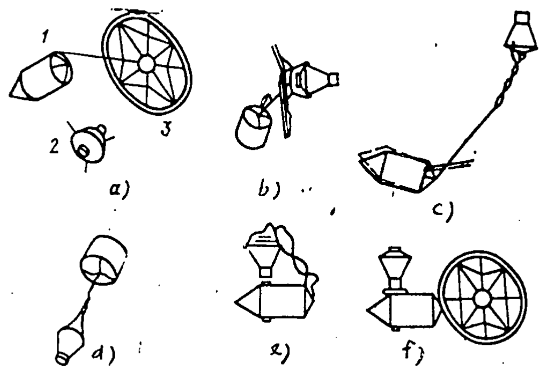

Figure 3.3. Diagram of docking-assembly with the help of towing and manipulating devices on the basic unit: a. rendezvousing of units; b. capture of structural unit by net; c. when the braking cable is unwinding; d. units being pulled together; e. alignment of the axes of the units' docking assemblies; f. docking-assembly of units with each other; 1. basic unit; 2. structural unit; 3. net.

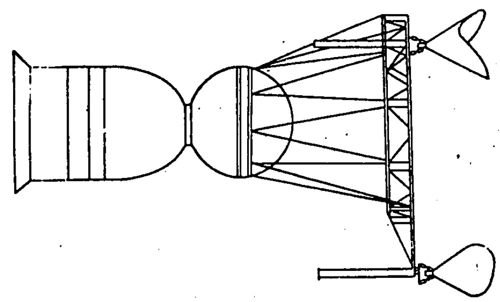

Figure 3.4. Assembly ship (diagram).

basic unit's docking assembly, and docking-assembly of the units takes place (Figure 3.3e, f). The capturing net can then be spread out again with the help of a remote manipulator, thereby making it possible to capture subsequent structural units sent from Earth and combine them with the basic unit.

In the near future we can expect the creation of a special space assembly system consisting of a space tug and an assembly ship (Figure 3.4) that, after being placed in orbit (with the help of reusable space transport ships), will carry out the assembly of individual structural units in orbit. In this case the assembly process will take place as follows (Figure 3.5): the space tug captures a structural unit sent into orbit from Earth and tows it into the assembly orbit. In the assembly

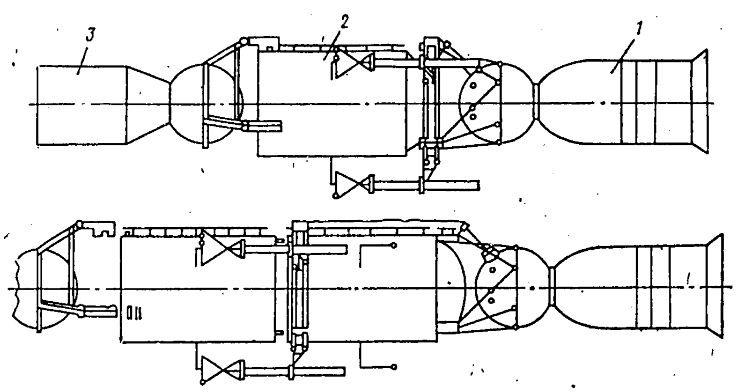

Figure 3.5. Diagram of assembly ship operation: 1. assembly ship; 2. structural unit; 3. space tug.

orbit, the space tug docks with the assembly ship with the help of simplified docking assemblies on the structural unit and the assembly ship, and "gives" the latter the structural unit (position 1, Figure 3.5). The space tug sets off for the next structural unit, and when it returns an automatic device for docking and coupling the structural units moves along the first structural unit, thereby making it ready to receive (dock with) the next unit being delivered by the space tug (position 2, Figure 3.5). The space tug delivers the next unit and the two structural units dock with each other. After the technological operation of connecting the units by some form of permanent connection (by welding, for example), a special, automatically operating installation sends the space tug for the next structural unit and the process of unit "accretion" is repeated. In this case the assembly ship is a unique robot--a complex cybernetic device. As technical and economic calculations show, as the size of space objects increases, so does the effectiveness of the utilization of assembly ships.

1.2. Creation of Objects From Transformable Structures

It is difficult to imagine the building of large objects in space without the use of transformable structures that are delivered into orbit in a folded, compact form. Special devices are used to transform these structures by unfolding (extending, inflating) them until they acquire the desired shape and size. In the future, these component parts of space objects will assemble themselves into a unified whole.

The use of such structures makes it possible to overcome the difficulties involved in transporting into orbit units for space objects that are of great length, area or volume, thereby providing a large savings of delivery facilities and increasing the transportation capabilities of existing launch vehicles.

Transformable structures must satisfy the following requirements: the structure must be of minimum volume during injection into orbit and of maximum volume (or area) after transformation (that is, it must have a maximum coefficient of structural transformation); the structure must have minimum mass and high strength and rigidity after transformation; the structure must be highly reliable and durable during extended use in open space (and must maintain its airtightness, when this is necessary).

Let us discuss the three basic groups of structures: extendable-inflatable (using materials with "memory" properties), extendable-bar and extendable-areal structures.

Extendable-Inflatable Structures. This type of structure includes those of the shell type.

Primarily, these are inflatable structures made of an elastic material or a plastic metal; they are delivered into orbit in the form of a compressed bellows in folded or compressed form, after which a gas is used to inflate them into their proper form.

Suggestions that inflatable structures can be used to build inhabitable and uninhabitable orbital stations have been heard for a long time. One of the basic requirements for an orbital station's shell is that it have low gas permeability and be durable enough to withstand collisions with meteorites (that it not tear apart when punctured). Automatic elimination of any openings that might form should be provided for.

High accuracy in the formation of a shell is achieved by controlling the internal pressure. The pressure in a shell or individual cavities in it is controlled by

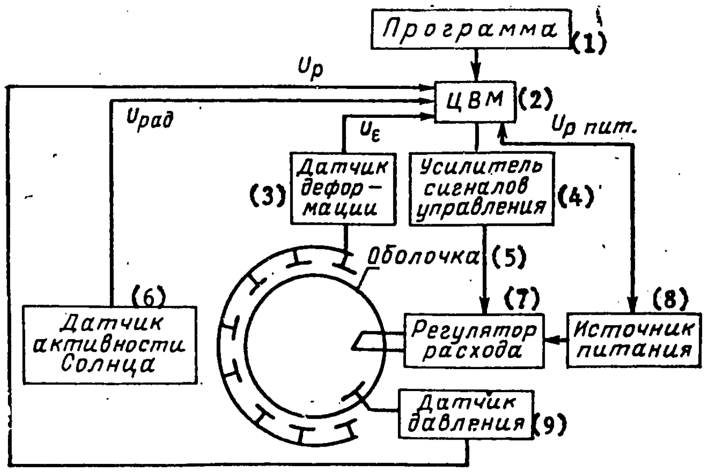

Figure 3.6. Block diagram of shape-change control system for a transformable shell.

Key:

1. Program
2. Digital computer
3. Deformation sensor
4. Control signal amplifier
5. Shell
6. Solar activity sensor
7. Flow rate regulator
8. Power source
9. Pressure sensor

feeding in the working body (usually a mixture of a gas and air). On the whole, the shape and size of an article is controlled on the basis of deviations of the intermediate article's parameters from the rated ones. Figure 3.6 is a functional diagram of a system for the automatic regulation of the gas shaping of a shell having a single internal cavity with controllable pressure. Signals from the pressure, deformation and solar radiation sensors enter a digital computer, where they are compared with signals corresponding to the rated values of the measured variables. When it receives a signal (U) that there is a deviation from the rated values, an error signal passes through the amplifier to flow rate regulator and power source, changing the gas flow rate and the voltage at the power source's output, thereby reducing the error signal. When the voltage corresponding to the assigned deformation of the shell is achieved, the shaping process ceases.

There is a great deal of interest in inflatable structures made of multilayered shells; they differ favorably from single-layer ones because of their great rigidity and greater safety factor during collisions with meteorites. Such a structure consists of inner and outer shells with a filler between them.

A structure is assembled in the following manner. A shell is manufactured that, when unfolded, has the shape of the future space object. It is carefully tested, after which the air is pumped out of it and it is folded and packaged. After delivery into orbit the shell is again inflated, with the pressure in the central part being higher than that in the peripheral compartments. Pipe connections are then used to inject a special liquid into the peripheral compartments' cavities, where it foams, fills the space between the inner and outer shells and hardens, thereby providing the structure with rigidity and protection against micrometeorites.

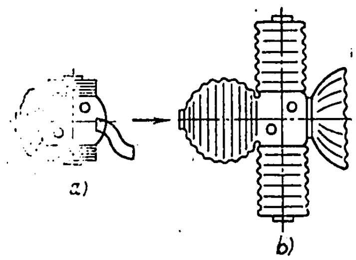

Figure 3.7. Space object made from transformable metal shells: a. before transformation; b. after transformation.

There is also a great deal of interest in metal shell structures of the bellows type that are manufactured on Earth from sheet metal and then folded. After they are delivered into assembly orbit, mechanical forces exerted by tension members or internal pressure that is the result of the injection of a compressed gas causes them to be transformed into a shell-hull with a large internal volume. Such structures can serve as the basis for future manned and unmanned objects that are to remain in space for a long time (Figure 3.7). The main advantage of such structures is that, along with compactness and small mass, they have a rather high degree of rigidity. In a situation where there are increased requirements for a structure's rigidity, it is possible to use additional internal reinforcing elements (plates, section irons, bars, frames) that are packed with the shell-hull in folded form before the structure is sent into orbit. Once in orbit they can be unfolded and the cosmonaut assembler can lay them out in the required position and perform the necessary metal installation work.

Transforming Structures Utilizing Materials With "Memory" Properties. A design for a passive communication satellite in spherical form has been patented in the United States. After it is launched into orbit and freed from its container, it unfolds when it is heated to a temperature above 65°C by some heat source (chemical, electrical) or under the effect of the Sun's rays. This type of structure can serve as yet another example of transformable structures. It consists of a metal-coated Mylar film shell and stiffening ribs made of a titanium-nickel alloy (nitinol [translation unknown]). This structure has the property of "remembering" the shape that it had at a high temperature. This is explained by the fact that when a 5-10 percent (no more definite figures were given) titanium-nickel alloy (TiNi) is bent, the alloy changes into $TiNi_2$ and $TiNi_3$, which change back into TiNi when heated above 65°C and cause the structure to return to its original form. When they are unfolded, the satellite's stiffening ribs resemble the meridians of a sphere, but when coiled spirally they can be packed, along with the shell, in the form of a circle or cylinder (depending on the shape of the container) of little volume. After being launched and freed from the container, the structure is heated to 65°C by (for example) connecting the stiffening ribs to an electric power source, whereupon it unfolds and stretches out into a shell. This type of structure can obviously also be used to make large space ships.

A rather large number of metal alloys are included in the list of materials that can "remember" a deformation.

Unrolling Sheet Bars. The hull of a spacecraft is subjected to the action of meteoric particles, which attack the surface layer of the shell forming its hull. In order to increase the service life of a spacecraft's hull, it is advisable to cover it with a special protective screen. In connection with this, there arises the necessity of manufacturing large shells from rolled sheet blanks.

A sheet-type shell is delivered into orbit in coiled (rolled-up) form, so the first stage in manufacturing a screen is to open the roll until it has zero curvature.

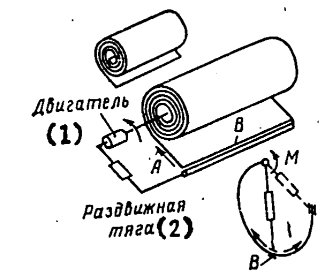

Figure 3.8. Diagram of unrolling of blank.
Key: 1. Motor
2. Extendable bar

With the help of a special device (Figure 3.8) for uncoiling the roll, it is necessary to create the torque needed to uncoil the blank. A monitoring device is needed to insure that the sheet has the required curvature.

The radius of curvature is determined by the length of the extendable bar. Final lapping of the shell's curvature is achieved by moving slide bar B in direction A and exerting the appropriate control over the moment of the unrolling mechanism's motor.

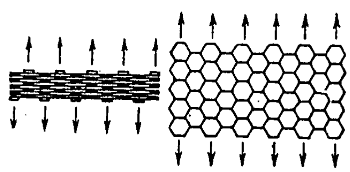

Figure 3.9. Honeycombs in folded and extended states.

After the sheet blank is unrolled and given the necessary shape and size, spiral welding can be carried out, thereby producing a protective screen or a cylindrical shell for a large orbital station.

Extension of Honeycomb Units in Space. The well-known method of making honeycomb units from foil (from an aluminum alloy, for example) can be used successfully as a technological process for manufacturing large platforms for orbital stations in space. Figure 3.9 is a diagram of the realization of this process. Under the conditions encountered in space, the process must be maximally automated.

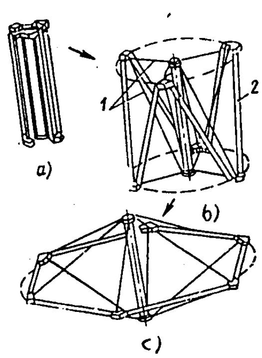

Figure 3.10. Module of the "umbrella" type: a. compact state; b. intermediate state; c. extended operating state; 1. brace; 2. rod.

The advisability of using this process in space is explained by the possibility of delivering into a satellite's orbit honeycomb units with unextended honeycombs. In order to build a large platform, it is necessary to use a transport spacecraft to deliver a honeycomb unit that is quite long but, at the same time, has a small cross-section. This unit must then be stretched out with the help of special but uncomplicated automatic devices. After this, it is sufficient to use any available method to place sheet material on both side of the extended honeycomb unit so as to form a panel filled with honeycombs. This type of structure can serve as the basis for the framework of a space object's assembly area or, for example, as a framework for solar batteries covering a large area.

Among the number of promising transformable structures we should include various extendable-bar structures of the "umbrella" type (Figure 3.10). In the folded state such a structure has a small volume. When acted on by the braces, the structure's rods can be extended and it will take on the required configuration; for example, it can be one of the modules of the framework of a space object that is large in area (such as a radio antenna).

1.3. Assembly of Large Objects With the Participation of Space-Walking Cosmonauts

Despite the fact that the spacecraft that have been launched in recent years have become larger and larger, in the future--as in the past--it will be impossible to launch large antennas, telescopes and other devices into orbit in a fully assembled state. Therefore, in open space it is necessary to have special methods for assembling large articles from separate parts outside a spacecraft. Let us discuss one of these methods, for the assembly of a large antenna in space.

An antenna in a modular version is the most attractive (from the constructional point of view) for the process of assembly outside a spacecraft. The panels of a modular antenna, which remind one of a honeybee's comb, are assembled in a manner similar to the way a concrete-block house is built. In connection with this, it is usually necessary to align and attach panels of the same size, which requires a minimum of equipment, skill and time. From the viewpoint of this type of assembly, we preliminarily analyzed a modular antenna 45 m in diameter that consists of 240 standard panels with dimensions on the order of 2.7 x 2.8 m (the longitudinal edges of the panels are slightly beveled, at an angle of about 7°).

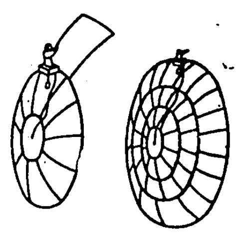

Figure 3.11. Structure assembled by the "escalator" method.

The so-called "escalator" method, where the cosmonaut stands on a special scaffold (Figure 3.11) and works as he moves along a guide rail, is extremely promising for this type of space object. He begins the assembly by attaching a standard panel to the circular (central) base section. When one row is assembled, he then assembles the second row and so forth until all 240 standard panels are in place.

The basic question in analyzing this assembly process was about a man's ability to move and put in place the relatively large panels.

An experiment in a "weightless" water tank showed that the average time for the installation of a panel measuring 2.7 x 2.5 m is no more than 0.8 min. Such data can be used when calculating the time required to assemble antennas. Using these data, it can be determined that the time required to assemble an antenna 45 m in diameter is about 400 min (or 6 h 40 min), including 1 h for the cosmonaut to rest.

However, it is obvious that for an antenna several kilometers in diameter, this type of assembly must be performed with the help of robots and manipulators.

On the Use of Robots and Manipulators in Assembly Operations. It has already been mentioned that with the increases in the complexity and size of space objects, their assembly in space will be impossible without the use of manipulators and, in the final account, assembler robots.

The creation of robots and manipulators capable of alleviating a cosmonaut's labor, and in some cases generally freeing him from the direct performance of some operation or another, is an extremely urgent problem.

Let us discuss several questions related to the prospects for using these types of devices in space technological assembly processes.

When a manipulator is in operation, its functions consist primarily of grasping solid objects and orienting them spatially.

In order for the actuating element of a manipulator to have the capability of moving and orienting in the appropriate fashion its grasping device and the object held in it, it must have at least three independent advancing and three independent rotating motions. Besides this, the grasping device must have yet another independent motion: opening and closing of the gripping jaws. It is frequently necessary to provide for additional degrees of freedom, so that it is possible to change the shape of the actuating element or expand the manipulator's area of operation.

A manipulator's actuating element must be light, flexible and strong, have a wrist-type joint for rapid attachment or removal of the gripping device, and have seven basic degrees of freedom.

The grasping and installation of parts in immobile elements of equipment that are mated precisely to them should be included in the category of manipulation operations of average complexity. In order to avoid the appearance of large stresses and insure the final installation of precisely mated parts, a manipulator's actuating element must have a certain degree of flexibility. Flexibility is provided either by elasticity of the actuating element or by slippage of the object in the grasping device.

The use of systems for searching for and "feeling" objects enables a manipulator to perform much more complicated operations and, on the other hand, lightens the re-requirements for mutual orientation of the objects to be assembled and the automatic unit. In this case the automaton and the object of assembly do not have to be mutually oriented and can be in any position and at any point in the automaton's operating range. If the automaton is equipped with a "visual analyzer," the search and identification process takes place in the optical channel, and only after it is completed does the mechanical hand go into operation. In this case the manipulator's hand can perform highly complex operations.

In order to perform a search, a manipulator's grasping device is usually guided by a sensor that carries out the functions of the automaton's "sensing organs." The automaton is controlled by a computer, the "memory" of which--in addition to the program's listed components--stores different subprograms, including a list of commands for setting the manipulator into motion. Structurally, a robot can be a device, part of the assemblies and systems of which are mounted on a mobile platform, while the other part of it is a control panel. Between the control panel (base) and the robot there must be communication channels that solve the following problems: transmit to the control point information gathered with the robot's help; transmit control information from the base to the robot; supply power to the systems installed in the robot.

Depending on the formulated structure of the overall system and the form of communication between the separate units, robots can be divided into the following groups: manipulating robots; semiautomatic manipulating robots with remote control and telecontrol; automatic robots with programming units; autonomous robots.

At the present time the most development work has been done on manipulating robots, which, by combining in themselves comparatively uncomplicated automata and programming units, possess a comparatively limited manipulating capability. The actuating elements used in them are devices that automatically perform a cycle of monotypical measuring, monitoring, manipulating and other operations. Such robot automata (manipulating automata) are completely determined systems. In order to "teach" a robot to do certain work, the operator must first, with his own hand, perform with the manipulator all the required operations for entry in the memory units of the manipulator's work program.

When working at great distances from the control point, and also in those cases where it is impossible to maintain reliable communication over the radio channel because of interference or other reasons, programming units can be used to control a robot.

11746
CSO: 1866/4

UDC: 629.78:530.24

THERMAL CONDITIONS IN SPACECRAFT

Moscow TEPLOVOY REZHIM KOSMICHESKIKH APPARATOV in Russian 1980 (signed to press 23 Jan 80) pp 2-6, 231-232

[Annotation, foreword and table of contents from book "Thermal Conditions in Spacecraft" by Vladimir Viktorovich Malozemov, Izdatel'stvo "Mashinostroyeniye", 957 copies, 232 pages, illustrated]

[Text] This book deals with problems of estimation, investigation and analysis by methods of mathematical modeling, with the use of digital and analog computers, of systems of provisions for thermal conditions (SOTR) in spacecraft. The principles involved in choice of design parameters with the use of optimization methods were demonstrated. This book is intended for engineering and technical personnel specializing in the field of SOTR for aircraft and spacecraft. It may be useful to instructors, graduate and undergraduate students of the relevant specialties.

Foreword

Life support for crews engaged in long-term space flights is one of the most important problems of cosmonautics. It is a complex task to solve it, and it requires much effort, as well as close collaboration of biologists, physicians and engineers in different specialties.

One of the most complicated elements of the general life support system (LSS), which creates and maintains the conditions needed for man's life and work in confined, sealed cabins, is the system of providing the thermal conditions (SOTR). Its task includes formation of a specified thermal level in a spacecraft, with due consideration of its correlation to the crew and environment in the presence of the complex effects of extreme factors. To solve this problem effectively, new approaches must be elaborated for developing, designing, studying and testing SOTR.

It is generally believed that it is sufficient to create stable thermal conditions, of the greatest comfort, within the pressurized cabin for normal well-being and high efficiency of man, both during flights and after returning to earth. In this case, man is viewed as a certain, specified, static object. However, data that have appeared in recent times refute this conception. Adaptive reactions of the body may weaken during a prolonged stay under relatively stable ambient conditions. Under such conditions, a change in one of the parameters, even when it is within the permissible range, could lead to loss of resistance of the organism and, consequently, to worsening of well-being and capacity for work. Good well-being and work capacity depend more on the dynamics of changes in ambient parameters, state of adaptive mechanisms of the organism, which was determined by the conditions under which man lived previously, than on the parameters of the environment at a given point in time (a man may feel well both in the extreme cold and tropical heat). For this reason, development of an SOTR, particularly for long-term flights, should be made with due consideration of its correlation with man, the environment and the construction of the spacecraft. Only such an approach, where man is viewed as the main element of a complex system, can assure development of a really effective SOTR that would guarantee the good physical condition and high work capacity of crew members.

There is another important aspect of SOTR design. When preparing for a flight, the crew undergoes special training with due consideration of future conditions, to which they will be exposed in space. As a rule, from the very first days of the flight, the crew starts to prepare for the return to earth, with due consideration of fulfilling the flight program. The SOTR, equipped with an appropriate conditioning program and devices measuring and forecasting the state of crew members and all spacecraft systems, could assume some of the functions of a training device when man is in space.

The SOTR is a complex consisting of functionally interrelated subsystems. Complex design and estimation of a multi-element SOTR , taking into cosideration the correlation between the crew and environment, as well as different subsystems, is a difficult task. The appreciable nonstationary nature of the main processes occurring at all phases of flight adds more difficulties of both analysis and choice of regulatory subsystems. There is still not enough experience in finding complex solutions to such problems. They can be solved on the basis of a new discipline, which has gained wide popularity and is related to analysis and synthesis of large systems, which is called systems analysis [8, 41]. Complex systems theory is the scientific, mainly mathematical, basis of systems analysis. Separation of real systems into complex and simple ones is largely arbitrary; it is related essentially to the extent of the role of complex "general systems" questions to the study of systems. This, in turn, depends on both the properties of the system proper and on the objectives of the study. With regard to the properties of a system, the presence of which enables us to refer it to the category of complex systems, we can state the following [41]: "We shall consider a system to be complex if it consists of many interrelated and interacting eleements. It is logical to expect that a complex system is capable of performing a complex function."

With reference to the SOTR of a spacecraft, it can be stated with certainty that it has all the main features characterizing large systems. The considerable number of complexly interacting elements, its link with the environment and man, justify our classification of SOTR in the category of large systems, the design, analysis and synthesis of which are made on the basis of systems analysis and general theory of systems. However, exhaustive knowledge is required to use this approach, both about processes that occur in typical elements and correlation between different units and sybsystems. It is only after studying all of the distinctions of the processes and correlation of elements of individual subsystems and complexes, and after constructing mathematical models thereof that we can turn to the systems methods of automated design and investigation with the use of modern computer technology.

To solve complex problems of design, analysis, synthesis and forecasting, it is the most expedient to use functional decomposition of the SOTR, drawing upon mathematical modeling to examine different subsystems and elements, including man. Structural and functional breakdown ["decomposition"] of systems and mathematical modeling make it possible to elaborate the methodology of solution and obtain concrete results for one of the functional subsystems, without losing the general aspect of the problem but reducing its dimension.

The book offered to the reader is an attempt to present systematized material on estimation, mathematical modeling and investigation of SOTR for spacecraft. The first chapter deals with general aspects of thermal provisions and a new version of system classification. The second chapter is concerned with analysis of external and internal heat loads. The next chapters describe different variants of subsystems for heat insulation and heat regulation. The different subsystems are examined on the basis of methods of mathematical modeling. Mathematical models are given for different elements and subsystems, and they are analyzed. Methods are described for studying mathematical models of SOTR elements and subsystems with the use of digital and analog computers. The last chapter discusses problems pertaining to choice of design patameters for SOTR.

Many of the problems raised in this book are still far from being definitively resolved. However, formulation and discussion thereof illustrate the importance and need of continued research in these directions.

This author considers it to be his duty to express his appreciation to Prof A. P. Vanichev, corresponding member of the USSR Academy of Sciences, for the valuable comments and advice offered when he reviewed the manuscript, as well as to Ye. N. Bondarev, doctor of engineering sciences, S. M. Bednov, candidate of engineering sciences, R. M. Kopyatkevich and other friends who examined the manuscript and expressed their wishes and suggestions, which were taken into consideration as much as feasible in the final editing of the book.

This author expresses his gratefulness to V. S. Pichulin, A. Ya. Donov, E. A. Kurmazenko, V. A. Tomskiy, I. I. Bogachev, S. N. Loginov, S. N. Kutepov, A. G. Bruk and T. I. Baranenkova for their assistance in the preparation of some of the material.

Without presuming to have shed exhaustive light on the topic, this author would be very grateful to readers for critical comments and suggestions, which should be addressed to: 107885, Moscow, GSP-6, 1 Basmannyy per., 3, "Mashinostroyeniye" Publishing House.

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SPACE APPLICATIONS

UDC 536.425:669.275'849

ZERO-GRAVITY METAL, SEMICONDUCTOR MELTING, CRYSTALLIZATION, PHASE FORMATION EXPERIMENTS IN SPACE

Moscow PLAVLENIYE, KRISTALLIZATSIYA I FAZOOBRAZOVANIYE V NEVESOMOSTI in Russian 1979 (signed to press 11 Sep 79) pp 2, 253-255

[Annotation and table of contents from book "Melting, Crystallization and Phase Formation Under Zero-Gravity Conditions", by L.I. Ivanov, V.S. Zemskov, V.N. Kubasov, V.N. Pimenov, I.N. Belokurova, K.P. Gurov, Ye.V. Demina, A.N. Titkov and I.L. Shul'pina, USSR Academy of Sciences, Institute of Metallurgy imeni A.A. Baykov, Izdatel'stvo "Nauka", 1200 copies, 256 pages]

[Text] Questions are discussed, relating to the performance of technological experiments in space for the purpose of an overall study of regularities in the behavior of metal and semiconductor alloys under conditions of zero gravity. A central place is set aside for the results of research performed within the framework of the Soviet-American experiment in the "Soyuz-Apollo" program. Features of certain kinetic processes under conditions of low gravity in a space flight are studied, as well as the prospects for utilizing these conditions for producing materials with special properties.

This book is intended for specialists working on problems of space technology and can also be helpful to students at technical VUZ's.

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