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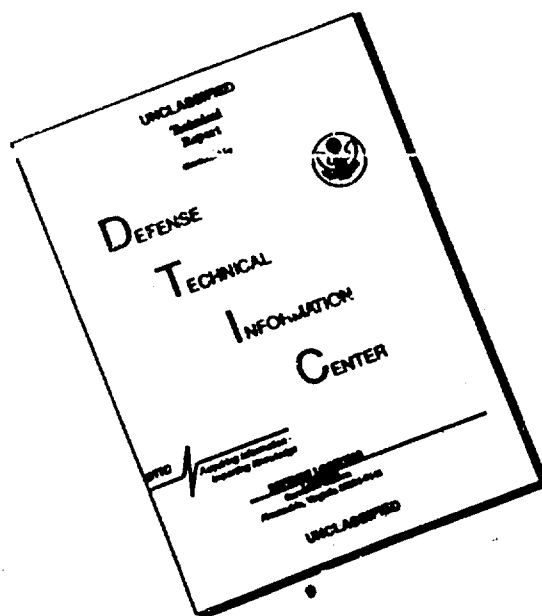
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BIOLOGY AND THE CONQUEST OF SPACE

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Following is a translation of an article by N. Sisakyan in Aviatsiya i Kosmonavtika (Aviation and Cosmonautics), Moscow, No 2, 1962, pages 24-30.

We live in remarkable times. It would seem that the most fantastic dreams are turning into reality. New, broad horizons are being revealed to us. The Party Program, greatest theoretical document of our era, orients our science toward extending research in all fields, including the field of space.

As initiated by the Soviet nation, the era of the conquest of space has brought into being a new, complex biological discipline -- space biology. No section of biological science has refrained from active participation in the development of the problems of conquering the cosmos.

In the last few decades space biology and medicine have travelled a great and glorious path. Its foundation was laid by the flights of experimental animals on geophysical upper-air rockets which rose to altitudes of 100 to 450 kilometers.

A great stride forward was the multiple-stage biological experiment with Laika in the second artificial satellite of the earth. It involved the testing of a large number of systems assuring the conditions of vital activity, and also tests of various automatic, radiotelemetric and other equipment. And although this experiment did not provide the possibility of investigating the coordination of movements, the state of higher nervous activity, and thoroughly studying the animal after the flight, it showed that the conditions of a prolonged flight, involving the effect of a large number of factors and of the prolonged condition of weightlessness, are quite endurable to the living organism. Manned space flights were preceded by staging experiments in space ships--earth satellites. Belka and Strelka, and later Chernushka and Zvezdochka, [dogs] were successfully returned to earth after orbital space flights and subjected to thorough study.

The scientists were thus able to derive conclusions about the complete absence of any negative effect of the flight.

In the future, the flights of animals and other biological objects probably will precede manned flights to other planets and serve as the necessary biological probes. However, only man can provide exhaustive answers to such questions as the ability to perform work, the effect of emotional and psychical factors, and the possibility of active participation in steering the spaceship and performing research work inside the spaceship. To many of these questions Yu. Gagarin has given exhaustive answers.

Yu. Gagarin obtained unique and invaluable scientific data. For the first time man has tested on himself all that is involved in a space flight, for the first time he has with a master's eye beheld the entire terrestrial sphere and informed the world with exceptional clarity about all that he has tested and seen.

The historic flight of the space ship "Vostok 1" was, so to speak, continued by the "Vostok 2." Borne on the mighty wings of science and technology, German Titov multiplied the outstanding accomplishments of the first cosmonaut.

One of the characteristic features of space flight is its duration. Therefore, we cannot rely only on the possibility of man's enduring strong but momentary effects. It is necessary to solve the problem of a prolonged sojourn in space. In this sense, G. Titov's flight is a qualitatively new stage in the development of space research, because it made it possible to make a definite conclusion about the condition and functions of the human organism during a 24-hour cycle of life under the special conditions of a space flight.

After the flight of German Titov it was established that, in the main, all physiological functions of the human organism had no pathological deviations.

The diurnal rhythm of respiration and heart activity was not disturbed in flight, and the level of the indexes of these functions corresponded to the activities which the cosmonaut was performing at the time. Thus, for example, when G. Titov was sleeping during the flight, his pulse rate was nearly the same as when he slept on the earth. The sleep was sufficiently deep and refreshing, and the cosmonaut awakened in a rested condition.

Titov steered the space ship successfully, made the necessary notations in the log, and maintained continuous contact with the earth.

It should be noted that the prolonged sojourn in space caused in G. Titov some changes as regards his vestibular apparatus, and this occasionally manifested itself through un-

pleasant sensations. However, when the cosmonaut re-assumed his original relaxed pose and made no abrupt head movements, these phenomena disappeared almost completely. It may be that the unpleasant sensations were a consequence of the specific, individual constitution of G. Titov. Therefore, the question of the state of a man under the conditions of prolonged weightlessness requires further investigation.

The results of research in space made it possible not only to obtain a large number of new and important scientific facts and evaluate the effectiveness of various systems of protecting life, but also to perceive and outline the prospects for further studies of the biological problems of future interplanetary travel.

It is especially necessary to study the effect of trips of a far longer duration, along new, unexplored routes; to develop new intricate systems for assuring the proper living conditions for the cosmonauts departing for distant and long-lasting voyages, and many other problems. However, the fact that our knowledge about the effect of cosmic factors on terrestrial phenomena, especially on the processes taking place in the atmosphere, is much fuller, opens tangible prospects for the future.

Scientists, including biologists, have begun to discuss with increasing frequency the prospects for future space flights. The representatives of empirical sciences are already, though with great caution, postulating their ideas as to the biological effects which may arise in the cosmonauts -- our descendants -- when flying in spaceships at a velocity comparable to that of light.

It is well known that scientists often dispute the solutions of today's scientific problems. The discussion of the scientific problems of the future is no exception. True, certain problems do not give rise to sharp discussion, and most of the researchers have a sufficiently clear and agreed-upon picture of these problems.

Thus, for example, astrophysicists and biologists agree that meteoric matter and the ionizing radiation of space can provide obstacles to future flights, especially if the flights are performed at extremely high velocities. It is time, as they justly believe, to consider developing reliable methods of protecting the men who shall fly in the interplanetary spaceships of the future.

Who has not seen, during a cloudless night, the "shooting stars" -- meteors which, flaring up and expiring, rapidly race across the dark firmament. This phenomenon, as is known, occurs as a result of the penetration of meteoric bodies into the atmosphere.

The meteorites which fall onto the earth's surface have a fairly complex chemical structure. Iron meteorites, for example, consist of iron, nickel, and cobalt; and stone meteorites, of silicon, magnesium, and their oxides.

Of special interest are the so-called carbonic meteorites. Their fragments turn out to contain hydrocarbons believed to be close to the hydrocarbons of the paraffinic series -- components of beeswax, and many other organic products. Finds of this kind compel serious consideration of the question whether organic matter may not be present throughout the universe.

The earth's atmosphere, like a suit of armor, protects the surface of the earth from falls of meteoritic particles. The matter is otherwise with planets which lack an atmosphere, for example, the moon. It is believed that the moon's surface is covered with a layer of meteoric dust and therefore pitted with a large number of craters, some of which are of meteoritic origin. Clearly, an encounter with meteoritic bodies can present definite danger to a spaceship.

The experience in the flights of artificial earth satellites and space rockets has, fortunately, shown that the "meteor danger" is not so great as might be imagined from theoretical calculations. Nevertheless, it may not be underestimated. It is self-evident that the problem of the meteor danger acquires a special importance to flights at velocities comparable to the velocity of light.

Is there any need to describe the possible consequences of a gap in the hermetic sealing of the spaceship cabin? It is common knowledge what this may entail to the spacemen. Naturally, the development of the necessary technical means of protecting the space ship and its crew is an important scientific and engineering problem.

What about the danger of radiation when flight speed approaches the velocity of light? Specialists in the field of cosmic ray physics note that the increase in this danger will be primarily related to the appearance of the so-called bremsstrahlung. They presume that the danger of radiation injury at velocities close to the velocity of light increases thousandfold if not millionfold. Although outer space is extremely rarefied (it is assumed that the density of hydrogen there is one atom per cubic centimeter), if the speed of a spaceship reaches three-tenths of the velocity of light, then, as a result of the interaction of interstellar matter with the frontal surface of the rocket, there arises a roentgen radiation of considerable intensity, which could be dangerous to the cosmonauts.

The danger of radiation injury, as physicists note, is

additionally augmented by the circumstance that during such an extensive flight toward some star the radiation spectrum of the latter will, according to the Doppler effect, be strongly displaced toward its violet portion. In this connection, the space ship will be exposed to increasingly intense waves of radiation with frequencies close to roentgen radiation.

To provide safe conditions for the cosmonauts during flight at extremely high velocities, the crew has to be reliably protected against penetrating radiation. In this connection the means of protection should be suited to the conditions of flight. These conditions cannot be evaluated without data on astrophysical studies of the presumed route of flight of the space ship.

It is known that, even as applied to the present-day practice, the danger of cosmic radiation depends on the orbit which will be followed by the space ship. It turned out that the intensity of this radiation differs not only in the regions of circumterrestrial space where, as is known, zones of higher radiation exist; it also differs in outer space. If it turns out that the route of the space ship traverses high-radiation zones, then either these zones will have to be bypassed or special means of protection will have to be developed.

Considering the prospects for future flights, it is impossible to overlook the possibility of the appearance of extraordinary conditions: the crew of the spaceship might be subject to some life-endangering external effects, or it might experience a calamitous shortage of oxygen, water, or food.

This problem might be solved through a considerable depression of the processes of metabolism, through bringing about in man a state close to anabiosis. The searches for and development of a method of artificially producing at the necessary time instant a state close to anabiosis or lethargy in man constitute a complex, intriguing, and exceptionally important theoretical and practical problem.

Thus, clearly, the meteor and radiation dangers are the most essential problems, whose satisfactory solution is a prerequisite for the possibility of manned interastral flight.

It seems that in the near future, to solve these problems, scientists will follow three paths: the development of a proper design of the shielding shell; flight along safe routes, with by-passing of the zones having a higher content of meteoritic matter or intensive radiation; and development of methods of physical, chemical, and biological shielding of the cosmonauts. One desires to emphasize that domestic and foreign scientists have outlined definitely encouraging prospects.

The solution of many problems of space biology is closely tied to automation, radio electronics, cybernetics, etc. The point is that, in contrast with the research conducted by biologists on the earth, any in-flight measurements involve the transmission of information by radio-telemetric systems. Biologic telemetry is the principal method of investigating and obtaining scientific information during the flight in space.

The use of radio telemetry imposes a specific imprint on the methods and equipment of biological experiments. Biologists and engineers who work in this field have to develop new data transmitters -- converters of physiological and biological indexes into electric ones, and they also have to develop automatically operating systems for operative control of any biological objects and cosmonauts in flight, and to continue the introduction of computer engineering for processing scientific data.

With the increase in the duration and distance of space flights, there arise the problems of automatic processing of biological information on board the space ship and the feeding of generalized results not only to the radio system but also to its control system. This requires special methods of encoding information, constructing rational algorithms for its analysis, and developing small-sized, economically operating, and reliable electronic digital computers.

It is clear to everyone that the members of the space ship crew need an atmosphere as well as food, water, and other conditions for normal living and working conditions during a prolonged voyage through outer space. The time factor places a vital imprint on the methods of assuring these conditions. It is a different matter when this concerns a trip to the moon or a flight in an artificial earth satellite for, say, a few days or weeks. Then the needed stores of oxygen, food, and water will not be large.

But what if the flight is scheduled to last a year, two, or more? Simple calculations show that the weight of the stores of food and oxygen would then run into astronomical figures, and the flight would simply not be realistic.

A considerable effect could be produced by installing in the cabin of the space ship a complete "water recirculation" system. The water consumed by man would be completely separated, collected and, by means of special equipment, purified. Such "regenerated water" would be suitable for human consumption.

Likewise, methods of restoring oxygen, which is necessary for respiration, have been explored: chemical, physico-chemical, and biological regeneration. The last-named is dis-

tinguished by a number of obvious advantages. The green plants placed in the space ship cabin would, as on the earth, as a result of photosynthesis, absorb carbon dioxide from the atmosphere and release oxygen. This will be accompanied by the synthesis of organic compounds, used to build up the plant's body. Thus there will be two important results: the enrichment of the atmosphere with oxygen and the synthesis of substances suitable for feeding animals and man.

Certain plant organisms such as, for example, the microscopic monocellular algae chlorella are distinguished by an especially high rate of oxygen production. The animals together with the plant create on board the space ship an artificial ecological environment providing food and oxygen to man.

This would mean creating in the space ship cabin a closed system of recirculation of substances, similar to what has long been existing on the earth. Only the circulation of energy will not be closed. It will have to be obtained from outside (for example, from the sun), accumulated, and transformed.

But all this far from exhausts the requirements for assuring a safe long-term and long-distance space flight. There also arise many other extremely complicated and partly completely new problems. Among them, a special place is occupied by psychology: the selection and mutual compatibility of crew members, the problem of the so-called state of suspension, or separation from the earth, and many other problems.

Since flights of the distant future, on interstellar ships, are considered, the time problem, too, cannot be overlooked. Scientists and science-fiction writers have been writing on and discussing the possibility of "time travel." The celebrated French mathematician Langevin, early in this century, basing himself on the theory of relativity, propounded the idea of the time paradox. This concerns the difference in age between the cosmonauts flying through outer space and the observers existing in a state of "rest" on the earth. It arises in connection with the slowing down of time during flight at a velocity close to that of light. This is a problem about which there is no commonly accepted idea among the physicists as well as biologists. It is being currently discussed whether the slowing down of time really does happen in biological systems, or whether this question is merely reducible to a difference in the reading of time between space travellers and their contemporaries who remain on the earth.

If a true slowing down of time really does exist, then the rate of biochemical reactions taking place in a living

organism during an interstellar flight should change -- and this inevitably involves corresponding biochemical and physiological changes.

Another important field of space biology is exobiology, whose task is to clarify whether there is life outside the earth, in outer space and on the planets of the solar system, and to determine the special features and forms of that life.

Various hypotheses about the existence of living matter on the celestial bodies of the solar system and in the universe as a whole are quite widely known. Unfortunately, more precise data are as yet very limited.

A further development of the concept of V. I. Vernadskiy about the earth's biosphere was the idea of the zone of life within the confines of the solar system -- the sun's exosphere. Proceeding from the premises that organic life based on carbon compounds is possible at temperatures of +80 to -70°C, the area of space with these conditions is located at a distance of 92 to 275 million kilometers from the sun. This zone contains three planets: Venus, Earth, and Mars, in which connection Earth lies almost at the very thermal center of the exosphere. Its mean annual temperature is about +14°C, while on Venus it is about +50°C, and on Mars, approximately -50°C.

All attempts to solve the question of the existence of life on Mars through observations from the earth have encountered great difficulties. It was only recently, upon using infrared spectroscopy in the darker areas of the planet (the so-called seas) that success was achieved in discovering absorption spectra considered characteristic of organic compounds of biological origin. Naturally, direct proofs of the existence of life on this planet and, the more so, studies of its specific features will become possible upon direct contact with the object of study.

Recently great attention has been attracted by investigations of the composition of carbonic meteorites. Most of them proved to be soluble in organic solvents and to contain a high percentage of carbon and oxygen. Upon a mass-spectroscopic analysis of the carbonic matter of the Orgeil meteorite hydro carbons close to animal products were successfully discovered, and the assumption about the existence of extraterrestrial biogenic processes was propounded. There exist indications that organic compounds and microscopic organisms of extraterrestrial origin may be discovered in the mass of the so-called Murray meteorite.

Restraint and caution should be shown when evaluating finds of this kind. Nevertheless, they merit the most concentrated attention.

New possibilities in this direction are being opened by the successes of cosmonautics, the prospects for establishing scientific stations in space. Clearly, it will be primarily necessary to clarify whether there exist in space the most primitive forms of life, elementary biochemical processes and substrata, both those similar to terrestrial counterparts and those different from them.

So far, there have been only hypothetical assumptions, among which the panspermic theory of Svante Arrhenius enjoyed the greatest popularity. The rather weighty objections raised against this theory are based on the injurious effect of radiation and the absence of a perceptible natural mechanism which might help the spores to overcome gravitational forces.

Nevertheless, results of researches make it possible to assume that certain hardy spore forms of microorganisms can exist and survive in outer space while migrating from one celestial body to another, or, for example, constituting a part of meteoritic particles.

Extraterrestrial microorganisms can adapt themselves to the extraordinary conditions of outer space by developing defense adaptations, changing the forms of their interaction with the environment. In this connection it is of interest to investigate the possibility of the existence of terrestrial forms of life and the manner of their adaptation to the conditions on other planets. There exist experimental proofs that certain anaerobic and quasi-anaerobic microorganisms are capable of adapting themselves to the conditions presumed to exist on Mars. It would be of great interest to investigate the extent to which these conditions can be endured by certain plants, especially lichens and mosses.

Thus, it can be assumed that the most primitive representatives of the earth's organic world do not necessarily have to die in space nor, a fortiori, do the organic substances have to disintegrate. There arises a problem of exceptional theoretical and practical importance: preventing the uncontrolled migration of terrestrial forms of life and terrestrial organic matter to other celestial bodies, as well as the migration of unusual forms of life to the earth.

The prospects of comparing the forms of life or biogenic processes encountered in outer space with their terrestrial counterparts are alluring to biologists. Such a comparison will make it possible to clarify the nature of the appearance and development of life in the universe, corroborate the unity of the pattern of development of living matter.

It is not difficult to see that the development of space biology will serve not only the purposes of interplanetary voyages and conquest of space by man. In the long run

this biology will contribute to constructing the most fundamental concepts of biology as regards the problem of life in general and solving, on this basis, important practical tasks.

When we turn to outer space, to celestial bodies, the possibility of future utilization of the energy resources of the universe seems to us inexhaustible and absolutely incomparable. It is hard to define at present the extent to which it will prove expedient to utilize the natural resources of celestial bodies or organic forms of matter for the needs of the earth. These problems are on the agenda of the day.

A result of their solution will be the discovery of new mysteries of nature, the strengthening of man's power over it, the progress of civilization, the happiness of future generations.