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Scope and Method of Study: This study has been undertaken primarily to enumerate the most basic and most commonly encountered problems which are inherent in the field of space medicine. The information presented in this study was taken from literature which has been written between 1950 and the early part of 1963. More recent literature has been published on this subject, but most of it is very specific and does not concern itself with these basic problems as does the earlier literature. The problems which are dealt with are problems which will exist in any type of space flight or space existence. The materials used in this study consist of general reference books, books specifically related to the subject, and journals which are significant in the field of science.

Findings and Conclusions: The science of space medicine is very young and very little actual experience dealing with its problems has been encountered. However, in the past few years, the realization of these has become much more apparent and some of them have been remedied through extensive study and experimentation. The most important problem in the field of space medicine is that of maintaining a suitable and functional environment for man as he investigates the realm of space. It has been proven that man can exist in space for short periods of time and do so in relative comfort. Man cannot, however, function in his full capacity at present because of the many limits imposed upon him by the planktonic existence in space. The invitation to intrigue which exists in space will doubtless lead man farther and farther into its expanses and more information will most certainly accompany him. New problems are inevitable, but these basic problems studied will always be present and will manifest themselves at any point outside the protective atmosphere of the earth.

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FIVE MAJOR PROBLEMS OF SPACE MEDICINE

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FIVE MAJOR PROBLEMS OF SPACE MEDICINE

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PREFACE

The problems of space medicine are very diverse and the workers engaged in work involving space medicine range from medical doctors to engineers. Many problems are encountered in space that are completely absent in medical science on earth.

The purpose of this study is to survey the major problems which determine the safety and provide for the survival of man in the hostile environment of space. These factors of man's survival and safety are an end result of technology. Before technology can be applied usefully, however, medical workers must experiment to determine the needs which must be satisfied by the technological facet of the program.

It must be realized that the science of space medicine is such a rapidly progressing field that new remedies and developments are constantly being brought forth. However, it must also be realized that the basic problems of space medicine exist and they must always be taken into account when space operations are undertaken.

Indebtedness is acknowledged to Drs. L. H. Bruneau, C. G. Beames, and F. J. Haddy for their assistance in choosing this topic of study. Special acknowledgement is due Dr. Bruneau in particular for his guidance in the preparation of this study and to Mrs. Verna Duckwall for the final preparation and typing. Dr. Robert Fite and the National Science Foundation also deserve a great deal of credit for the financial aid which made this study possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART I

INTRODUCTION

With the development of an engine which is powered by a fuel that is independent of atmospheric oxygen for combustion, a new term has entered into the field of medical science. This new fuel makes possible travel beyond the atmosphere of the earth into the almost perfect vacuum of space. The new term is space medicine. (Strughold, 1961).

In atmospheric flight the flier always remains to a certain extent under the protection of the atmosphere and is able to reach in a few minutes its safer lower regions. In space flight there is no surrounding atmospheric environment at all; it is a new medium for movement. (Strughold, 1961).

Space medicine is that area of environmental medicine which deals with the medical problems from flights to and in the upper atmosphere and outer space. Space medicine is an extension of aviation medicine which deals with the human problems arising from flights in conventional civilian and military aircraft. The term space medicine was coined when the first Department of Space Medicine was established at the USAF School of Aviation Medicine, Randolf Field, Texas, in February, 1949. (Haber, 1961).

The chief task of space medicine, of course, is to study the effects of the space environment upon the human body and to develop protection devices in all cases where a hazard of health exists. In this work the development of aviation is directed toward ever increasing heights so that one space factor after the other will be encountered. (Haber, 1961).

Space medicine belongs in the categories of both industrial medicine and environmental medicine. Its existence as a portion of industrial medicine is shown by its role in the design and engineering of space vehicles. It is also an integral part of environmental medicine because it is concerned with a completely different environment than the one known to atmospheric operations. (Strughold, 1961).

PART II

CLASSIFICATION OF SPACE OPERATIONS

Classification and medical characterization of the various conceivable kinds of space operations typifies the initial problem to be confronted by space scientists. Four basic types of space operations are said to exist. These types have been separated somewhat arbitrarily and each has been given a particular descriptive name. The names given each respective type are: atmospheric operations; space equivalent operations; satellite operations; and, lunar, interplanetary, and planetary expeditions. Thus far, only the first three types have been actually experienced. The fourth is now in the planning stage only. (Strughold, 1961).

The number and diversities of medical problems involved in this four-stage program are readily unveiled by a general survey of the various craft, dynamics, velocities, environments, and gravitational conditions to be encountered during these endeavors. (Strughold, 1961).

It is already evident that in the final stage of this four-stage program, the time factor will be of the essence. Time duration of the flight will obligate space-medical research to center its attention and planning on merely keeping man alive in his small space environment in addition to all the other problems inherent in such a maneuver. (Strughold, 1961).

PART III

ECOLOGY OF SPACE

Since space medicine is a part of environmental medicine, its problems and their solutions are derived from considerations of the environment of man and machine in the upper atmosphere and in space. The difference between man's normal environment on the surface of the earth and the environment of space is determined by the atmosphere of the earth. The atmosphere renders a number of important functions for living organisms, including man. With increasing heights above sea level, the atmosphere thins out rapidly and finally blends with the extremely attenuated cloud of gas and dust known as interplanetary matter. By the same token, the normal environment existing at the surface of the earth is gradually transformed into the environment of space. (Haber, 1961).

Space is essentially an environment of radiations both of the electromagnetic and corpuscular kind which may originate from either the sun or galaxies. The solar electromagnetic waves range in length from 10 angstrom units to 10 meters and all travel at the speed of light. The corpuscular rays or particle rays consist of electrons and protons which are nuclei of hydrogen, nuclei of helium or alpha particles and nuclei of heavier atoms ranging up to the iron group. These travel at various speeds, some approaching the speed of light. When the rays attain or surpass a certain kinetic energy level they are called cosmic particle rays. (Strughold, 1961).

Space also contains very thinly dispersed gaseous matter (mainly hydrogen), and dust particles (about 1 per 10 cubic meters). Neither of these types of matter are found in any appreciable amount, nor in any measurable amount. (Strughold, 1961).

Still another type of matter exists in space in the form of meteorites which range in size from the size of a human white blood cell to large lumps of matter. (Strughold, 1961).

Two phenomena of space are consequent to this sparseness of matter. They are a darkness of space and a silence of space owing to the lack of a proper medium to transmit these two forms of energy. (Strughold, 1961).

"How high must one go above the earth's surface in order to leave the atmosphere behind and enter space?" This seems to be a very important question in space-medical research. (Strughold, 1961). Caidin (1962) states that the absolute limit in altitude before pressurizing equipment is obligatory is the point at which the barometric pressure is 11 per cent of that at sea level. This situation exists at approximately 10 miles above sea level.

Eleven per cent is the minimum pressure because at sea level, carbon dioxide and water vapor make up 11 per cent of the gases in the lungs. At 20,000 feet for example, they still make up 11 per cent. The percentage of carbon dioxide and water vapor does not change. At 50,000 feet the occupant has left behind him 89 per cent of the atmosphere. Air density and pressure are down to 11 per cent of what they are at sea level. Now, considering that carbon dioxide and water vapor make up 11 per cent of the entire mixture of gases in the lungs, and that the air pressure is only 11 per cent of normal, the two figures have met. The percentage of carbon dioxide and water vapor inside the lungs is the same as the air pressure both inside and outside the lungs. The occupant is strangling. (Caidin, 1962).

According to astrophysical theories, the outer reaches of measurable atmosphere extend approximately 600 miles above the surface of the earth. However, this figure has little relevance to the actual problem of the transition from atmosphere to space as it concerns space medicine. (Strughold, 1961).

The interrelations between the human organism and the air are rather complex. The various factors of the space environment, therefore, are apt to appear at different altitude levels. In fact, one finds a series of such critical levels, one for each particular element of such critical levels, one for each particular element of the functional relationship between a human being and the ambient air. In the terminology of space medicine such a critical level is called a functional border of space. The various functional borders can best be described by considering the different functions which the atmosphere fulfills for man and machine. The functions are essentially three-fold:

1. The function of supplying pressurized air and a suitable climate;
2. the function of supplying a filter against cosmic factors; and,
3. the function of supplying lift and drag. (Haber, 1961).

Haber (1961) deals with these three functions in greater detail and describes each of them as follows: 1. The atmosphere is capable of meeting the respiratory needs of man only if the breathing air is pressurized to a certain degree. The barometric pressure existing between sea level and about 15,000 feet is sufficiently great to meet this condition.

Quantitative information as to the extent to which atmosphere can contribute to the respiratory needs of the human body above 15,000 feet is obtained through experiments with explosive decompression. In experiments of this kind a subject is transposed, within less than one second, from an environment of slightly reduced air pressure to an environment of sharply reduced air pressure such as would be found at higher altitudes. It is then found that a certain time after the decompression, the subject loses consciousness. This critical time span is called the time of useful consciousness. If the air pressure after decompression corresponds to that found at 30,000 feet, the time of useful consciousness is about 2 minutes. At greater heights, this time is shortened, and finally reaches a constant value of about 15 seconds at an altitude of 52,000 feet or about 10 miles. (Haber, 1961). As low as 10 miles, the atmospheric oxygen ceases to enter the lungs because the alveoli are filled with water vapor and carbon dioxide issuing from the body itself to the full barometric pressure of 87 mm of Hg found at this altitude. (Strughold, 1961).

In experiments made in the low-pressure chamber at simulated altitudes up to 12 miles, the time of useful consciousness remained constant at an average of 15 seconds. (Haber, 1961). However, according to Strughold (1961), at about 12 miles above sea level the corresponding total air pressure (47 mm of Hg) is no longer effective in keeping the body fluids in the liquid state. Strughold (1961) also states that at an altitude of about 16 miles the air, owing to its low density, can no longer be utilized for cabin pressurization: instead, a sealed cabin is needed; the same type as is required in space.

Thus, at 10 miles above sea level one finds the borders of space as far as man's respiration is concerned. Above this height, artificial air pressure must be supplied within an airtight shell and additional protection must be provided for pilot and passengers in the form of emergency pressure suits or space suits. (Haber, 1961).

2. The reduction of atmospheric pressure at greater altitudes also changes drastically the climatic environment of the pilot. Closer to the ground, the temperature of the craft is determined chiefly by the temperature of the ambient air. Higher up, the exchange of heat between the air and the craft ceases, and its skin temperature is governed by the exchange of radiation between the craft on the one side, and the sun, the earth, and the free space on the other. However, this radiation climate in its pure form will prevail only at altitudes in excess of about 70 to 100 miles because in rockets, airplanes, missiles, high skin temperatures are encountered owing to air friction. Because high-altitude flight always implies fairly high speeds, the functional border of space in terms of radiation climate is found at 70 to 100 miles above the surface of the earth. (Haber, 1961).

The atmosphere acts as an effective filter against various cosmic factors that are potentially dangerous to high-flying craft. These factors include solar untraviolet radiation, meterorites and cosmic radiation. (Haber, 1961).

The bulk of ultraviolet radiation from the sun is effectively blocked by the ozone layer extending between 20 and 30 miles above sea level. The upper layer of this zone marks the functional border of space concerning solar ultraviolet radiation. (Haber, 1961). Strughold (1961) states that at 28 miles the atmosphere absorbs the sunburn producing ultraviolet rays of solar origin. According to Haber (1961), this kind of radiation is potentially dangerous because of its ability to produce erythema of the skin and conjunctivitis. In severe cases the latter can lead to serious eye injuries and even blindness. It has been estimated that above the ozone layer these effects can be produced 10 to 50 times as fast as at sea level.

Meteorites are a potential danger because of their excessive speeds. Meteoric speeds range between 7 and 40 miles per second. When colliding with a ship even small meteorites are capable of piercing the shell of pressure cabins thus causing a more or less sudden loss of cabin air. Most meteorites are absorbed by the atmosphere of the earth within the zone lying between 65 and 95 miles above the ground. This zone, therefore, determines the functional border of space with respect to meteorites. (Haber, 1961). A more specific altitude was cited by Strughold (1961) at which the atmosphere loses its ability to absorb meteorites. He set the limit at 75 miles above the ground.

At 24 miles the atmosphere no longer absorbs cosmic rays and they are encountered in their primary form. (Strughold, 1961).

Cosmic radiation consists of atomic nuclei, chiefly hydrogen and helium nuclei, that enter the atmosphere from all directions of space. Their speed is close to the speed of light, which is indicative of their enormous specific energy. In 1948, the nuclei of heavier atoms were also found in cosmic radiation. In traversing the terrestrial atmosphere, the primary cosmic ray particles produce a complex array of reactions with atoms and molecules of the air, with the result that they are either completely absorbed or greatly reduced in their energy when they reach the ground. The air layers above 23 miles are too thin to have any appreciable effect upon the cosmic rays; so far as cosmic rays are concerned, space-equivalent conditions are encountered above this height. Cosmic rays are a potential hazard because of their power to produce ionization in the human tissue they traverse. It is therefore a great space-medical interest to what extent cosmic rays would cause the various symptoms of radiation sickness or do isolated damage to certain organs of the body. (Haber, 1961).

3. At greater heights above the ground, the atmosphere becomes so thin that aerodynamic lift and drag vanish. From then on the air is no longer capable of supporting the craft. If at that point, the rocket engines are silent, the craft is no longer subject to an external force. (Haber, 1961). Strughold (1961) cites an altitude of 30 miles to be the limit of aerodynamic lift and flight of winged craft, and an altitude of 75 miles to be the limit of aerodynamic heat production regardless of the speed of the craft. Beyond this point, the temperature of the wall of the cabin is determined exclusively by solar radiation.

Finally, at about 120 miles, air resistance approaches zero. This point marks the termination of the effective atmosphere; the final functional border. Beyond lies a condition of weightlessness for both man and craft. (Strughold, 1961).

The condition of weightlessness is not likely to produce any disturbances in the major physiological functions such as respiration and circulation. One must, however, expect that weightlessness will produce a certain degree of disorientation, dizziness and sickness; disturbances must also be expected in the control of body movements. (Haber, 1961).

Mention should also be made that light in space, according to Strughold (1961), is an important ecological factor of space medicine with regard to vision and as potential energy for photosynthesis by the algae which is a food producing organism for use in space flight. He states that at an altitude of 60 miles the rarified air ceases to scatter light which in the lower, denser atmospheric region produces indirect sunlight results in a dark sky despite a bright, shining sun. This condition is known as darkness of space. Also, at about 60 miles, propagation of sound terminates (silence of space).

The material above concerning the functional borders of space is summarized in Table I according to the information presented by Haber (1961) and Strughold (1961).

TABLE I

FUNCTIONAL BORDERS OF SPACE

Function of the Atmosphere	Limiting Altitude Miles
Contributing to Respiration	10
Absorbing Cosmic Radiation	23-24
Absorbing Solar Ultraviolet Radiation	28-30
Preventing Weightlessness	40-60
Transmitting Sound	60
Reflecting Light	60
Absorbing Meteorites	65-95
Producing Aerodynamic Heat	75
Preventing a Pure Radiation Climate	70-100
Producing Air Resistance	120

Just beyond the final functional border of the earth's atmosphere, the earth still has some effect. The ultimate environment of true interplanetary space is yet to come. The earth still plays a small, though important role in the total profile of the space flight. The earth's shadow, its own heat radiation and reflected solar radiation influence the heat balance of the space vehicle and pose special visual problems. (Strughold, 1961).

PART IV

GRAVITY AND MOTION IN SPACE

The major topic of this area with which medicine in space is concerned is the speed necessary to escape the gravitational pull of the earth and the force man would encounter at this speed. Force is measured in this particular instance as a function of g (gravity). This will become very important when interplanetary travel in space is accomplished. (Strughold, 1961).

Assuming the gravity of the earth to be 1.0 and the escape velocity necessary to leave the earth's gravitational field to be 7 miles per second (25,000 miles per hour), a passenger would be subjected to an acceleration of 10g. (Strughold, 1961).

The relative gravity and escape velocity of other bodies known to exist within our solar system are shown in Table II and are based on the preceding paragraph.

TABLE II

GRAVITY AND ESCAPE VELOCITIES OF SOLAR BODIES

Solar Body	Gravity g	Escape Velocity Miles Per Second
Mercury	0.27	2.2
Venus	0.85	6.3
Earth	1.00	7.0
Mars	0.38	3.1
Jupiter	2.64	37.0
Saturn	1.17	22.0
Uranus	0.92	13.0
Neptune	1.12	14.0
Pluto	--	6.0?
Moon	0.16	1.5

Because of the characteristics of rocket propulsion, man, during the ascent of a rocket vehicle is exposed to accelerations which range from 1.5 to about 7g, thus imposing a heavy weight on the human system. For example, at 7g the blood has the same specific weight as liquid iron. Although these conditions put organic operations under heavy stress, they are by no means intolerable. When lying flat on his back and accelerated normal to the direction of the spine, man can stand considerably higher accelerations, namely 20 to 30g, for, of course, shorter periods of time. These accelerations of more than 7g are much more readily accepted by the human organism as a unit if the acceleration acts in a direction from chest to spine. Man is considerably more sensitive to accelerations acting parallel to the spine because of the sensitivity of the human brain to blood deficiency or excessive blood pressure. Man's position with respect to the direction of acceleration or deceleration must therefore always be carefully controlled. However, if this is done, the limiting factor of acceleration is not the tolerance of the pilot or the passenger but the structural strength of the vehicle. (Ehricke, 1961).

To help overcome the force of acceleration, the g-suit is worn by the occupant of the craft. The g-suit looks like cutaway football pants which contain five pneumatic bladders. One of these bladders is located on each leg at the calf, one on each thigh, and one across the abdomen. When the g-force reaches and surpasses an acceleration of 2g, the bladders are automatically filled with air. These bladders exert pressure on the lower portions of the body and cause the blood to be kept in the upper portions of the body so as to prevent blackouts.

The g-suit gives an astronaut an additional tolerance of 2g. (Caidin, 1962).

Although accelerations as high as 35 to 40g are generally lethal, man may be killed by much lower accelerations, if the acceleration changes very rapidly. For example, man accelerated from 1g to 2g in 1/2000 of a second is likely to die. However, such rates of change do not occur normally in space flight. In fact, much higher accelerations may occur during parachute bail out at high subsonic or supersonic speeds. (Ehricke, 1961).

PART V

THE LIFE SUPPORT SYSTEM

Caidin (1964) states that the man who goes into space never really leaves his planet behind him. No man can really abandon the earth. To survive in the hostile environment of space, he must take part of the earth with him.

Space medicine is not an exact science like physics or engineering because of the large degree of individual variation in tolerance to various stresses, and because of the wide range of adaptability of the individual to biologically marginal conditions. In space flight, any deviation from man's comfort region demands adaptation (large or small), and each adaptation will reduce the individuals vital reserves, leaving him more susceptible to other stress and hastening the development of a state of fatigue. Thus, comfort is of the very essence in manned space flight. (Ehricke, 1961).

Engineering of the space cabin is the central task of space medicine. The space cabin must serve as the astronaut's home during the flight. Although this home is but a temporary one, it must possess virtually all the comforts of home in regard to physiological and functional operations. In this instance, space medicine and space technology are somewhat inseparable. (Strughold, 1961).

1. Generally speaking, the space cabin has a purpose which is twofold: It must protect the astronaut from external, potentially

hazardous factors; and, 2. it must afford the astronaut all the vital necessities for survival and comfort as far as possible. (Strughold, 1961).

One of the external dangers is meterorites which travel at excessive speeds. However, they are not found in large numbers, generally. Most meteorites are of cometary origin and have a low density, hence being very fragile. In reference to frequency of meteorites, the "hit frequency" decreases with increasing size of the meteoric bodies. (Strughold, 1961).

Meteorites are capable of causing two different effects on the space vehicle. These are puncture and surface erosion. (Strughold, 1961).

The danger of puncture of the sealed cabin by meteors is very small. However, if it occurs, it may be accompanied by two phenomena: shock wave, followed by a high-temperature air layer traveling across the cabin; and, sudden decompression within the cabin. The higher the initial cabin pressure, the greater are the hazards encountered in the case of sudden decompression. The hazards are caused by the immediate physiological effects of rapid pressure loss and by the results of exposure to extreme lack of oxygen. The severity of the first effect depends upon the rapidity and magnitude of the decompression. Gases (especially nitrogen) contained in body cavities and fluids immediately tend to expand in proportion to the reduction of ambient pressure. Where the escape of these gases is obstructed, such as in the intestine and the lungs, extreme pressure may result. Furthermore bubbles form in the blood and body tissues. The result, known as the bends, is exceedingly painful and may, in cases of nearly explosive decompression, be fatal. (Ehricke, 1961).

Tests in low-pressure chambers have decreased much of the original concern about sudden decompression. During these tests, sudden decompression as fast as 0.01 second has been tolerated. A compromise pressure between comfort and the need to cushion the impact of sudden decompression is 5 to 7 pounds per square inch absolute. This low pressure is still comfortable if the partial pressure of exygen is kept constant at 2 pounds per square inch, reducing the cabin pressure solely by reducing the partial pressure of the nitrogen. The partial pressure of the water vapor must also be kept constant at 1 pound per square inch. Even more important is the loss of oxygen due to sudden decompression. The lack of oxygen (hypoxia) leads to unconsciousness and may paralyze man's effort to help himself during a sudden decompression. Therefore, it is necessary to provide for an automatic pressure regulator for the cabin. An automatically inflated pressure suit is a technically simpler solution but more inconvenient to the pilot or crew, so it can be used for flights which last only a few hours. (Ehricke, 1961).

There are two methods which may be employed to prevent puncture by meteorites or at least to remove the danger from it. First, a secondary hull or meteor bumper may surround the cabin to absorb the kinetic energy of the colliding meteoric body. Secondly, self-sealing devices may be used to seal any puncture which does occur. These devices must be automatic because the astronaut could be stricken by a brief period of unconsciousness and be unable to seal it himself. (Strughold, 1961).

According to Slager (1962), most meteorites will not puncture a spaceship, and the few that do penetrate will produce relatively small defects. Such small holes, if detected in time, are not catastrophic and may be repaired quite readily.

Ehricke (1961), however, states that no protection is known against collision with a meteorite the size of a small pebble or larger, but that such an event is highly improbable.

Erosive effects of fine, otherwise harmless meteoric material on the exposed surface of the cabin may affect the transparency of the windows, the maintenance of radiative heat balance of the cabin and the utilization of electronic equipment. Ideal protection from this problem would be a protection comparable to that given the surface of the earth by the atmosphere. (Strughold, 1961).

Radiation, in principle, constitutes a serious biological hazard. One may distinguish three types of radiation. Corpuscular radiation from solar flares consists primarily of protons and electrons. These may penetrate the walls into the life support system if no adequate shielding is provided. Soft electron radiation may not be able to penetrate the hull of the spacecraft. If the hull is metallic, the absorption of electrons will produce x-ray photons and thus may turn the spacecraft into a gigantic x-ray machine. (Ehricke, 1961).

Cosmic radiation (cosmic primaries) easily penetrates the vehicle's walls, regardless of thickness, and produces serious damage to a small group of cells which it penetrates. (Ehricke, 1961).

The third basic type of radiation is that known as secondary radiation which results from the interaction of the cosmic primaries with other nuclei. (Ehricke, 1961).

In order to avoid the x-ray effect, it may be necessary to avoid metallic parts as much as possible in the structure and interior of the crew capsule. An alternative is the use of an inner lining of lead or copper to absorb x-ray radiations, or at least reduce such radiation to a safe level. The latter method involves a great weight penalty. (Ehricke, 1961).

According to Ehricke (1961), no protection is known against the cosmic primaries. A vital group of cells or a vital physiological regulatory center could be destroyed by cosmic primaries.

Cosmic radiation and its potential hazards to health have been the subject of numerous research projects. Theoretical studies have shown that damage, if any, can only be expected from the heavy nuclei of primary cosmic radiation. (Haber, 1961).

In experimental studies, animals have been flown in skyhook balloons to heights up to 100,000 feet (19 miles) where the density of the heavy component is close to that found in empty space. Mice and more primitive biological specimen have thus been exposed to cosmic radiation for several hours. From these studies, the conclusion emerges that short-time exposures to cosmic radiation to do constitute a serious hazard to health. Less is known about these effects, however, after longtime exposures. (Haber, 1961).

Based on these experiments with mice, Ehricke (1961) states that only in the small group of cells producing pigment at the base of each hair follicle does the probability exist that a complete group cell function might be destroyed.

Secondary radiation, genetically speaking, appears to be the most dangerous. It can be reduced significantly by avoiding metal walls and equipment, the main source of secondaries, or at least by an inner lining with material containing a large amount of hydrogen which tends to absorb the secondaries. Organic materials, such as rubber, are also very promising. (Ehricke, 1961).

The study of radiation has revealed this situation: The primary particle rays will penetrate, unchanged, the hull of the cabin or they will be transformed within the material of the hull into secondary rays, and these will penetrate the interior of the cabin. The purpose of the shielding must then be to block the primary cosmic rays and to reduce the secondary rays to tolerable levels. This shielding must also be capable of coping with unanticipated intensification of radiation during increased solar activities. (Strughold, 1961).

Visible radiation or light in space is also cited by Strughold (1961) as a potential problem. The sun shines brightly, but on a dark sky because of the absence of indirect sunlight. This causes an eerie, bright illumination inside the cabin because the cabin reflects the direct light. Thus special light scattering glass must be used in the cabin which will diffuse the solar light before it actually enters the cabin. Direct sunlight not only causes discomfort to the eyes but it also may lead to retinal damage such as retinitis solaris and retinal burns (helioscotoma).

Slager (1962) describes abnormalities and pathologic changes which can result from exposure to radiation. These conditions are described in brief below.

<u>Microwaves</u>. Microwaves are radio waves which have a wave length ranging from 10 cm to 1 mm and a frequency ranging from 3,000 megacycles per second to 3,000,000 megacycles per second. Microwaves

affect tissue chiefly by heating. The tissue receiving the damage is usually of the superficial nature, such as the skin and eyes. (Slager, 1962).

There is a possibility that space pilots may be exposed to controlled amounts of microwave energy during earth-based training to increase their resistance to solar radiation effects. Experiments with test animals showed that those who had been exposed to the controlled amounts of microwave energy prior to a strong x-ray exposure were much less susceptible than those who received x-ray exposure initially. (Alexander, 1962).

Infrared radiation. Biologically, infrared radiation is equivalent to radiant heat. Heat energy affects biological material mainly by excitation of valence electrons. This produces altered chemical bonds and results in thermal denaturation of proteins and coagulation, necrosis and death of the cells involved. (Slager, 1962).

Visible light. The main effect of visible light is on vision and the visual organs. This is due to the severity of direct illumination and the lack of illumination of the background. Visible light may also have a notable effect on the skin in the form of erythema in which lesions are produced. (Slager, 1962).

Ultraviolet radiation. The initial danger from ultraviolet radiation is that the body is provided with no method of detecting their presence. However, the actual hazard lies in their effect on the skin, such as carcinomas (malignant growth of outer body cells) and skin lesions. Most of the damage does not reach the dermis, but concentrates in the epidermis. (Slager, 1962).

The conditions mentioned above are caused by radiation which is designated as non-ionizing radiation. Slager (1962) also describes conditions which result from x-rays, gamma rays, beta rays, and alpha particles, collectively known as ionizing radiations.

Ionizing radiations. In biological material, continuing metabolic activity magnifies the original defect caused by ionizing radiation until definite celluar malfunction and destruction can be observed microscopically or even grossly. The observable cellular defects include enzyme inhibition, inhibition of DNA and protein synthesis, inability to divide, protein denaturation, and chromosomal abnormalities. Different types of damage have different thresholds of sensitivity. (Slager, 1962).

Of particular importance in space flight is the environmental control of temperature and humidity. For comfort under the living conditions of a space vehicle's pilot or crew, the temperature should not fall below 15°C. The upper temperature limit is a function of humidity, being about 19°C. at 70 per cent humidity, and about 27°C. at 30 per cent humidity, and varying linearly between these limits. (Ehricke, 1961).

Humidity in a sealed cabin is essentially determined by the moisture given off by the occupant through respiration and perspiration under normal temperature conditions. Man will release 50 to 80 grams per man per hour under these conditions. Comfort limits range from 30 to 50 per cent relative humidity when temperature is kept within normal range. (Strughold, 1961).

Critically high humidity can be caused by failure of the moisture absorbing system which is made up of chemical absorbents. Critically high temperatures may occur during re-entry from space into the atmosphere and consequently, a refrigeration unit may be required. (Ehricke, 1961).

Temperature is an expression for the average kinetic energy of particles which is most useful in near equilibrium conditions in the dense regions of the atmosphere. Temperature does not hold this connotation in space, however. Even though space is never completely devoid of particles and may contain between one particle per cc and 1,000 particles per cc, it has a low density compared to the atmosphere. The kinetic energy is very high, but such a small number of collisions results that enough energy to affect the temperature of the space ship is not produced. Thus, beyond an altitude of some 80 to 100 miles, heat transfer between the craft and the environment by conduction and convection ceases. Thermal equilibrium in space is governed only by radiation. (Slager, 1962).

Temperature of the space vehicle is determined by its distance from the sun, the time spent in the shadow of some celestial body, the radiation from that body, the shape of the vehicle, and the type of surface which covers the vehicle. This surface covering is provided by a special reflective paint. (Slager, 1962).

According to Strughold (1961), temperature within the space cabin is determined by the difference in heat gain and heat loss. Heat gain is a derivative of various factors both inside and outside the space cabin. Heat is produced within the cabin by such things as lighting, auxillary equipment and body heat of the occupant or occupants. One man produces roughly the same amount of heat as a 100-watt electric light bulb. Slager (1962) states that man in space contributes about one third of the total heat within the space cabin, while batteries, compressors, and other equipment contribute the remaining two thirds.

Heat sources outside the cabin include aerodynamic heating during launching, atmospheric entry and solar radiation. Aerodynamic heating is very brief but very extreme and is, therefore, a problem for technology rather than medicine. (Strughold, 1961).

The optimum intracabin temperature range is from 70 to 80°F. Temperatures within this range are achieved by the surface of the craft which governs amount of reflection and amount of absorption of solar heat radiation. (Strughold, 1961).

The human body temperature must be kept within certain limits if it is to function properly and efficiently. If this temperature range is not maintained, one of the conditions briefly described below will result.

Hyperthermia. Hyperthermia is the condition of the body during an excessive retention of heat. This condition is due to either excessive heat production or decreased heat loss. It is accompanied by an increase in body temperature which is known as hyperpyrexia. (Slager, 1962).

Hypothermia. Hypothermia is a state in which the body loses more heat than it produces. It is usually accompanied by a decrease in body temperature or hypopyrexia. (Slager, 1962).

Presently, the problem of maintaining a proper pressure environment is under full research and development. Pressure cabins and pressure suits have been built and are being used under operational conditions. Further improvements are under way, and the design of fully equipped space suits is being considered. The problems of rejuvenation of cabin air are under study, including the removal of respiratory waste products from a completely enclosed body of cabin air. (Haber, 1961).

Air pressure within the cabin must conform with both physiologic and technologic boundries. Pressure of sea level value is the most desirable physiologically. However, this may need to be increased or decreased during particular phases of the flight for technological reasons. This presents no real problem or creates no real crisis on the part of the occupant because the variation would be small and easily tolerated physiologically. The heavy shielding against cosmic rays and meteorites makes the problem of pressure regulation a comparatively small one. (Strughold, 1961).

At 50,000 feet and higher, with no artificial oxygen supply, a man can stay conscious for only ten or fifteen seconds before he faints. Death comes almost as quickly. (Caidin, 1962).

Some men have shown signs of hypoxia at altitudes where the oxygen was normally sufficient for conscious and controlled behavior. The cause of this was found to be a lack of red blood cells which carry the oxygen to body tissue. Thus, a large degree of selectivity must be executed in the choice of an occupant for a space flight. (Caidin, 1962).

The importance of the maintenance of pressure in space can be shown by citing some simple but amazing facts. First, it is known that water boils at 212°F. if it is at sea level where the atmospheric pressure is 14.7 pounds per square inch. But, at 63,000 feet the pressure is so low that water will boil at 98°F. The body is filled with fluids, including blood, which is about 92 per cent water. Also, the body produces heat and it operates at a temperature of 98.6°F. From these figures it is readily seen that the heat of the human body is great enough to boil the fluids within itself at an altitude of 63,000 feet. That is, unless the pressure can be maintained at a near normal level. (Caidin, 1962).

A low atmospheric pressure or a complete absence of pressure may cause various abnormal responses which can eventually lead to death. Some of these abnormalities are described below according to Slager (1962).

Dysbarism. Dysbarism is a disease entity which results principally from the formation of gas bubbles in the body tissues and fluids as a consequence of exposure to a swift decrease in barometric pressure from an initial pressure of one atmosphere. This condition is analagous to the symptom complex known as the bends or decompression sickness. (Slager, 1962).

Aerotitis media. Aerotitis media is an acute or chronic traumatic inflammation of the middle ear caused by a pressure difference between the air in the tympanic cavity and that of the surrounding atmosphere. (Slager, 1962).

Hypoxia and Anoxia. Anoxia refers to a physical situation in which no oxygen is available to the body, and hypoxia refers to the state in which insufficient oxygen is available to the body. A related condition known as hypoxidosis is one in which the metabolic demands of the body cells and the supply of any agent which takes part in cell metabolism are out of proportion to each other. (Slager, 1962).

Ebullism. Ebullism is the boiling of body fluids at body temperature because of the low pressure. (Slager, 1962).

The great concern about these factors is that if the pressure is suddenly lowered, all these conditions may appear simultaneously. The hazards involved are obvious, indeed. (Slager, 1962).

Many types of tests and observations relating to effects of high altitude flight have been made possible by the development of the decompression chamber. This airtight chamber is capable of simulating flights to altitudes at which dangers from lack of pressure are very grave. If ill effects or unanticipated problems should arise, the pressure can be increased to normal in only seconds. (Caidin, 1962).

Respiratory gases and other metabolic products constitute another problem of the maintenance of life in the space cabin. Assuming a standard man to be one of 154 pounds, he will consume some 600 liters of oxygen per day and release some 500 liters of carbon dioxide per day. This problem can be surmounted, during relatively short duration flights, by processes of control by replacement and storing and/or elimination. This is achieved by replacing consumed oxygen from tanks, chemically absorbing carbon dioxide and water vapor and by storing liquid and semiliquid waste products. The maximum time limit for this type of metabolic control is near two months. Beyond a flight duration of two months, another method of control must be employed; the recycling method. This method might allow flight durations of up to one year maximum. The recycling of respiratory gases is readily accomplished by the well known process of photosynthesis (Fig. 1). (Strughold, 1961).

It has been found that approximately 2.5 kilograms of fresh weight of the alga Chlorella pyrenoidosa are capable of meeting the respiratory requirements of man. Research is being done at present in the

$$6CO_2 + 6H_2O + \text{radiant energy} \dashrightarrow C_6H_{22}O_6 + 6O_2$$

Fig. 1. Photosynthesis

direction of finding even more efficient strains of green microorganisms for this purpose. (Strughold, 1961).

In addition to the liberation of oxygen, photosynthesis builds up carbohydrates. Science is now in the process of learning how these carbohydrates may be used directly as food for the space traveler. (Strughold, 1961).

Two compounds, both superoxides, show great promise as reliable sources of fresh, comfortably dry air free of contamination. The compounds are extremely active oxides of potassium and sodium. (David, 1961).

One canister of either potassium or sodium superoxide will accomplish all the things which must be done to purify used air: it removes carbon dioxide; it removes some water; it removes digestive gases such as indole and skatole; it removes bacteria; and, most important, it produces oxygen. (David, 1961).

A supply of such superoxides to last one man one day would weigh only about 4 pounds and would not require heavy containers that must be used for liquid or highly pressurized oxygen. In addition to the chemical, the only other major equipment is a very compact blower and heat exchanger. Therefore, like weight, volume presents no problem. The system operates at ambient pressure and therefore no risk of high pressure failure is involved in the fittings which are employed. Also, the system is very simple mechanically because it has a minimum of complicated valves and moving parts, and the chemicals used will always react for their total given life. (David, 1961).

In the event of a failure on the part of the superoxide system, oxygen can be supplied by chlorate candles which are manufactured from iron powder, sodium chlorate, glass fibers which bind the materials, and barium peroxide which prevents the formation of chlorine gas. When ignited, these candles produce medically pure oxygen until they are consumed. The residue is an inactive, harmless ash. One of these candles the size of a cigar can provide a 15 minute supply of oxygen for one man in an emergency. (David, 1961).

Man's requirement for food is an important aspect of not only space medicine, but also engineering, because it involves weight and packaging problems. Therefore, man's needs should be met at the minimum weight and volume requirements possible. Man has been found to require 2 pounds of oxygen, 1.5 pounds of food, and 4.8 pounds of water per day. This is a total of 8.3 pounds per man per day. His output is found to be 7.9 pounds per man per day, the difference owing to the growth phenomena such as the growth of hair and nails. Water, being the bulk of this weight, must be cycled and used again during operations in excess of one to two weeks of flight. (Ehricke, 1961).

The space suit as it is commonly referred to is not a true space suit because it is still not completely independent of the space cabin. However, it is a definite part of the life support system and the description below applies to the suit worn by the astronauts which participated in the Project Mercury program. (Caidin, 1962).

Mention should be made at this time of the miniature switchboard which is worn by the astronaut beneath the space suit. It is worn over his heart and is attached by wires to various parts of his body. This switch board relays messages to doctors on earth as to the astronaut's condition and his reaction to various stages of the flight. These messages report on some twenty different body reactions of the astronaut while on the launching pad, during ascent, while in orbit, and during descent. Included among the recorded reactions are heartbeat, respiration, and body temperature. (Caidin, 1962).

Actually, a true space suit is one which can be worn in space and survival can be derived from the suit alone. Such a suit is a complete life support system because it is not connected to the capsule or space vehicle in any way. It enables the astronaut to leave the safety of his vehicle in space and yet remain alive and well. The suit allows him to carry, on his person, his oxygen supply, heating, cooling, ventilation, and all power sources. However, such a suit is not yet in use. (Caidin, 1962).

The suit worn by the astronauts of Project Mercury is only part of the entire life support system of the capsule. These suits receive power from the capsule, just as an unborn child receives life-giving material from its mother's body. (Caidin, 1962).

The basic function of this space suit is to maintain pressure in the event of sudden decompression of a very severe nature. Under the pressure suit, a double-walled ventilated rubber garment is worn. The inner of these two walls is perforated to permit "breathing" of the skin and perspiration. The perforations also allow oxygen to warm or cool the body and to evaporate the perspiration. The outer suit is made of a single layer reinforced rubber. The only time full pressure is applied to the outer suit is in an emergency, at which time the pressure is forced into the suit automatically. The last major portion of the space suit is the helmet. It resembles a football helmet somewhat and has a plastic facepiece. The helmet is fastened to the suit by a special locking neck ring. (Caidin, 1962).

Undoubtedly, the first thing one notices about the space suit is its brilliant silvery appearance. This, also, has a particular purpose and function; that of protection against heat. The suit will reflect heat away in the event of severe temperature exposure. (Caidin, 1962).

This process which has been discussed, by which life is sustained within a cabin which is hermetically sealed, is referred to by some as a closed ecologic system and it is, indeed, just that. (Strughold, 1961).

PART VI

WEIGHTLESSNESS

The basic dynamic pattern of a space flight trajectory consists of an active (power on) phase, a passive (power off) phase of coasting, and atmospheric re-entry. The first and last of these phases are associated with high accelerations and decelerations. The phase between the two which represents the actual motion situation in space is characterized by zero g or weightlessness. In space, flight weightlessness is not a function of the distance from the earth's gravitational center, rather it is a matter of motion dynamics and can, potentially, be produced everywhere. It occurs when the gravitational pull of the earth is balanced by inertial or centrifugal forces originating in the vehicle by its motion. (Strughold, 1961).

Space medicine concerns itself with two basic questions involving weightlessness and its effect on the human body: 1. What is its effect upon the somatic nervous system? That is, what is its effect on mechanical body performance? 2. What is its effect upon the autonomic nervous system and the vegetative processes controlled by it, such as respiration, circulation, digestion, and on the general well being? (Strughold, 1961).

Weightlessness is difficult to assess, mainly because it cannot be properly simulated on the earth's surface. Tests involving the parabolic arc flight by planes produced weightlessness for only a few seconds and results were recorded. However, the results were thought to be inclusive because the short period of weightlessness did not permit complete physiological adjustment on the subject's behalf. (Ehricke, 1961).

Effects of weightlessness have been studied experimentally on animals as well as on human subjects. Mice and small monkeys have been sent up in research rockets and some of them have been exposed to weightlessness for about four minutes. As expected, respiration and circulation were not seriously disturbed in the animals; they did, however, exhibit some signs of confusion. (Haber, 1961).

Most human subjects who participated in the parabolic arc flights experienced disorientation and disturbances in muscular control in varying degrees of seriousness. The symptoms are reduced after a subject has taken a number of such flights. (Haber, 1961). Such tests did indicate, according to Ehricke (1961), that some persons had less difficulty entering a state of weightlessness than did others. Part of the problem of weightlessness in manned space flights is solved, therefore, by proper selection.

Research has shown that performance is not affected greatly by the condition of weightlessness after the subject has orientated himself to it. Following brief, initial deviations neuromuscular control and coordination became satisfactory, especially when supported by visual control. Also, the feeling of falling is generally absent, particularly if the subject is aware of the situation and knows he cannot fall. (Strughold, 1961).

The human body possesses several sense organs equipped with specific nerve endings that serve as mechanoreceptors, such as the centrally located otolith organ in the inner ear, and the group of peripheral mechanoreceptors such as the pressure sense receptors distributed over the entire skin--Meissner's corpuscles and nerve endings on hairs, and muscle spindles--and finally, nerve endings in the connective tissue surrounding the muscles known as Pacinian corpuscles or posture sense. All of these receptors have an exteroceptive function, in that they react to external forces and inform us about the outer world such as manifestations of the gravitational pull of the earth in the form of weight. They also have an enteroceptive or proprioceptive function in that they inform us of the tension conditions of the skin, the muscles and the connective tissue. The otolith organ and the pressoreceptors in the skin have a more pronounced exteroceptive function than do the other mechanoreceptors in which the proprioceptive function is dominant. (Strughold, 1961).

In a gravity free state, the exteroceptive function of the mechanoreceptors is eliminated; the proprioceptive function, however, is not. This explains why after some familiarization, performance of neuromuscular tasks is not particularly imparied. For orientation in this situation, the absence of the exteroceptive function is compensated for by the eye. The eye is the only sense organ that can furnish this type of information during space flight. (Strughold, 1961).

The otolith organ in the inner ear and those mechanoreceptors found in great numbers in the peritoneum of the abdomen have strong reflex connections with the autonomic nervous system which controls such things as circulation and motion of the stomach and intestine. (Strughold, 1961).

The behavior of respiration and circulation during the weightless state has been recorded in animals such as the Russian dog, Laika. The general result was that there was a general tendency to decrease in the activity of these functions. The most noteworthy effects were associated with the transition from increased g to zero g, rather than during a prolonged period which was consistently at zero g. (Strughold, 1961).

It was found, also, that blackouts of human subjects during brief periods of high accelerations up to 6.5 g lasted longer when they were followed by zero g. It may be assumed from this that the most critical effect of weightlessness on the vegetative process will be encountered during entry into space and re-entry into the atmosphere. (Strughold, 1961).

Many other vegetative factors will be considered as space flights become longer in duration. All the factors concerned with nutrition and elimination of body wastes will become of major importance. Among these are the problems of swallowing comfortably, drinking liquids, and micturition. The first of these has some potential danger involved. Consumption of liquids is provided for by squeeze bottles instead of open containers, and micturition has been shown by research to be possible under a condition of weightlessness although the familiar urge which generally precedes urination is not experienced. (Strughold, 1961).

When space vehicles are built on a larger scale to permit movement within, handrails, magnetic shoes and other special equipment will have to be employed. (Strughold, 1961).

In his publication concerning this subject, Slager (1962) presented the information shown in Table III which follows.

TABLE III

PERIODS OF WEIGHTLESSNESS EXPERIENCED BY MEN AND ANIMALS DURING ACTUAL SPACE FLIGHTS

Vehicle	Experimental Subject	Duration
Sputnik II	Dog: Laika	7 days
Vostok I	Yuri Gagarin	89 minutes
Mercury	John Glenn	4.2 hours
Vostok II	Gherman Titov	25.0 hours

On April 12, 1961, Yuri Gagarin of Russia, was blasted away from the earth. The following is Gagarin's personal response to the feeling of weightlessness according to Caidin (1962).

> Once I was in orbit, once I was separated from the carrier rocket, I experienced weightlessness. At first this sensation was somewhat unusual, even though I had experienced it before for short periods. But I quickly became accustomed to this sensation of weightlessness, adapted myself to this situation, and continued to carry out the program which was set to me during flight.
> ...During the orbital flight I took food and drank water. I maintained constant radio contact with the earth along several channels both on telephony and telegraphy signals. I made observations of the conditions of my environment, of the functioning of the equipment of the space ship. I made reports back to earth, made entries of the observations in my logbook, and recorded them on a tape recorder.
>
> My feelings during the entire period of weightlessness were excellent and my capacity for work was fully maintained.
>
> It became easier to do everything when I became weightless. This was quite natural. One's legs, arms weigh nothing. Objects float in the cabin. Neither did I myself sit in the chair as I did before that, but hung in midair. While in the state of weightlessness I ate and drank and everything occurred just as it does here on earth.

A second Russian cosmonaut, Gherman Titov, remained in space for twenty-five hours. He ate three full meals in space and, in one instance, spilled some fruit juice. The juice droplets floated in front of his eyes and according to Caidin (1962), described it as follows:

> They floated like berries before my face. They remained suspended in the air scarcely quivering. Finally, I caught them in the top of the tube and swallowed them.

Titov also reflected on some of his other experiences and observations at zero g. When asked how he slept, he said:

> In order not to become separated from the pilot's couch, I attached myself with straps and gave myself the order to sleep. We cosmonauts have been trained by physicians to fall asleep instantly when desired, and to wake up exactly at a given time. ...I usually sleep well and never dream. On the flight I slept according to plan. Through my fault I even slept a little longer than necessary. Anyway, there was no time to dream. I was supposed to rest, after all. I slept soundly but my couch was of course not a pillow made of down.

Concerning the total effect of weightlessness, Titov made the statement which is below. (Caidin, 1962).

> Weightlessness does not interfere with man's capacity for work. I was in a weightless state for a long time but successfully carried out all the slight assignments and I could draw only one conclusion: Weightlessness does not interfere with life and work.

In his publication, Carpenter (1962) gave his own account of the condition of weightlessness and it's effect on him personally. He stated:

> The weightless environment is very welcome and very wonderful. There is no difficulty in accomodating to this state. I went through some movements with eyes closed and eyes open to test proprioceptive cues to the body under this weightless state, and I am happy to report that no bad effects were noted due to weightlessness.

The most dramatic effect of weightlessness is probably phychological rather than physiological. The person being subjected to this condition may be inconvenienced by it and may find tolerance difficult, although no actual functional or organic harm results.

PART VII

CONCLUSION

Manned space flights are expected to bring substantial benefits to earthbound medical problems in many fields. Advances in medical instrumentation, understanding of the nervous system and brain functions, and increased knowledge of biological functioning are expected to be incorporate in the benefits received from these programs. (Randt, 1961).

Two-man Gemini spacecraft will provide a space laboratory facility of significant value for aerospace medical research compared with the shorter duration, one-man Mercury system. (Bulban, 1963).

Gemini will have a 100 per cent oxygen environment, pressurized at 5 pounds per square inch. Tests of up to 14 days have shown no physiologic reasons to prevent use of the 100 per cent oxygen atmospheric environment. There was some concern relating to calcium control by the body, acceleration tolerance, middle ear pain, and oxygen toxicity in such a situation. However, these fears were alleviated by the tests. (Bulban, 1963).

A significant part of the Gemini tests will consist of: determination of what is normal physiological data; means of juggling or varying metabolic needs of the astronauts during the course of long flights; the interplay of cardiovascular and respiratory systems; and, the definition of rest and work cycles. (Bulban, 1963).

The potentialities in the space age, as discussed in astronautical literature, appear to be limitless and the velocities mentioned appear to have escaped all meaning. However, this is not the case from a medical standpoint. Definite limitations do exist and must be considered carefully. (Strughold, 1961).

The limitations of manned space flight are determined by two factors: 1. the extreme regional variations of the physical environments of space itself and the degree of hostility of the environment found on the celestial bodies; and, 2. the time involved, or the duration of the flight which is closely related to velocity which by itself can become a limiting factor. (Strughold, 1961).

The limitations of the first factor are very similar to and even overlap the factors which were considered in the discussion of the space cabin. Temperature, solar illumination, and other factors relating to solar effects are the basic sources of limitation in this respect. These problems are inherent in travel which takes man farther away from, or near to, the sun. (Strughold, 1961).

The second factor, that of time, presents problems in recycling and storage in addition to required velocities. This is exemplified in that a flight to the Moon and the return flight can be made in less than a week; a flight to Mars and return, based on minimum velocity requirements would take eight months. Also, if the velocity were increased, the collision energy of meteorites and dust particles would be higher and the impact energy of the cosmic rays striking the craft from any of many directions would be greatly increased. Velocities of near light speed are, in many respects, considered favorable in interstellar flight. However, it is hardly feasible that such flights will take place within the realm of the coming century and we must concern ourselves with the problem at hand, which is survival within our own solar system. (Strughold, 1961).

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