# SPACE MEDICINE

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For the past fifty years the concept of flight has been generally associated with that medium close to and around the Earth known as the atmosphere. Just recently, however, it has become associated with the vast area beyond the atmosphere, namely, interplanetary Space.

Flying in the atmosphere takes place technically by support from the air. The same holds true from the physiological or medical point of view, even though - with increasing altitude - some atmospheric deficiencies are artificially compensated by means of oxygen equipment and pressurized cabins. This type of flight includes both prop and jet propulsion and is, in its very nature, travel by air. Props and jets are in the true sense of the word - airplanes; both are dependent upon the air as a medium for mechanical support or lift, and as a source of oxygen for combustion of the fuel. Therefore, both can be expected to have altitude limits because of decreasing density of the atmosphere. In fact, those limits lie at about 12 miles for the propeller plane and at 15 miles for the jet plane. Beyond these respective levels the density of the air is too low to provide sufficient mechanical support or lift, and too low to supply enough oxygen for combustion of the fuel. So, in conquest of the air ocean, props and jets have reached the limits of their capacities. Aviation medicine has contributed greatly toward making flight within these operational ranges of the atmosphere possible, safe, and efficient.

The technical possibilities in aviation, however, have not yet been exhausted. Human genius has invented a new engine for propulsion, an engine that does not require the presence of air; an engine that is based on the principle expressed by Newton's third law of motion -"For every action there is an equal but opposite reaction." This device, known as the rocket engine, is independent of air as a supporting medium; in fact, it is even more efficient in the absence of air or in a vacuum.

The rocket, therefore, has no limitation in altitude whatever. Its operational range is determined exclusively by its fuel supply. In the realm of rocket flight the concept of height above the earth's surface gradually fades into that of distance from the Earth. The rocket alone has really conquered the third dimension or vertical dimension in flight. It has opened a new frontier - the "vertical frontier"; On this frontier the units of measure are no longer "feet or meter", instead, we use "mile or kilometer." Mountains are no longer obstacles to be avoided; rather, they appear to the flyer as mere geological wrinkles on the earth's surface. And clouds present themselves as surface features like the clouds do on other planets, when they are observed through a telescope.

Just as the rocket has no altitude, likewise it has practically no speed limit. As to the form of motion, the rocket does not move under a steady acting power of propulsion like the propellor plane, instead, after an initial period of acceleration it can be regarded as a pure projectile, following the laws of ballistics and even those laws that govern the movement of celestial bodies - as will be explained more in detail later.

These two facts - one, that the environment in rocket powered flight is not the atmosphere but more or less free space, and the other, that the rocket itself during a large part of its motion behaves like a celestial body - indicate that we have entered a novel revolutionary phase in the development of flight.

We are at the threshold of space flight. This of course is of great importance to the Air Force and has attracted the attention of its many fields of endeavor. That new field of science which studies the human factor involved, and which will contribute greatly in making possible, and safe, this kind of flight, is Space Medicine, a recently founded branch of Aviation Medicine.

It is indeed a great honor and a pleasure to have this opportunity to acquaint you with the medical problems encountered in space flight or rocket flight.

The medical problems in space flight arise, primarily, from the differences between the strange environment found in space as compared to the environmental conditions found in the lower atmosphere to which we are accustomed. Naturally, these differences are more drastic than those encountered in conventional high altitude flight. Some of the most important ones are:

1. The atmosphere, at and near sea level, contains a rather high concentration of oxygen, needed for respiration; - in space there is no oxygen.

2. The atmosphere exerts upon us a certain barometric pressure that maintains our body fluids in the liquid state; - in space no barometric pressure exists;

3. Up to a certain altitude, the atmosphere can be used for the pressurization of the cabin; - in the emptiness of space there is no ambient air available.

4. In the lower zones of the atmosphere we are protected against the intense solar and cosmic radiation by the atmosphere's filter function; - in space no such natural protection

can be expected;

5. The same holds true for the meteorites;

6. In the atmosphere, light is scattered by the air molecules, producing our diffuse beautiful blue daylight; space is permanently in a mysterious state of twilight with the stars visible all the time.

These are some of the environmental differences between the atmosphere and space that are of special interest to us.

The atmosphere as a material continuum extends to about 600 miles; this is the physical border of the atmosphere in terms of the astronomer or meteorologist. Beyond this border, after passing through an extremely thin spray zone of single free moving air molecules, we enter the almost perfect vacuum of interplanetary space; but, from the standpoint of manned flight, we arrive at a different aspect of the borders of the atmosphere.

The various functions of the atmosphere that I have just enumerated, do not terminate all at once at the astronomical border of the atmosphere of 600 miles; instead, they cease one by one at different altitude levels of the atmosphere, some even rather relatively low. For example: the function of the atmosphere in supplying us with oxygen - for physiological reasons - ceases at 50,000 feet, just as if there were no oxygen pressure at all; the air pressure becomes insufficient to keep our body fluids in the liquid state at 63,000 feet, just as if there were no air pressure at all like in Space; the filter function of the atmosphere concerning cosmic rays and the sunburn producing ultraviolet of solar radiation, ceases at 120,000 and 140,000 feet respectively; and the atmospheric protective function against meteorites comes to an end at about 75 miles. Logically, these facts lead to a different aspect regarding the border between atmosphere and space. From a medical or physiological point of view it is not the astronomical border at 600 miles that counts, but rather the cessation of the various atmospheric functions at the various levels just mentioned. We call the atmospheric levels where these functions cease, the functional borders of the atmosphere. At these functional borders and above them, we encounter spacelike or space equivalent conditions with regard to the particular function in question. This knowledge gives us the answer to the questions "Where does Space actually begin for the flier?" and "Where do we stand today in the advancement of space flight?" But before we are ready to discuss, however, we must bring in a few more points to complete the picture.

In the early thirties, the pressurized cabin was introduced to protect the flier against the effects of decreased air pressure and oxygen pressure. Air is pumped into the cabin from the outside by means of compressors and is kept at a comfortable pressure. This method is used in all military high altitude planes and in the commercial airliners of today. But this conventional pressure cabin is not useable within the entire vertical range of the atmosphere with its spacelike properties, and has its altitude limits. It can serve our purpose up to an altitude of about 70,000 to 80,000 feet only. Why?

At an altitude of 80,000 feet, the density of the air is only about 1/25th of that at sea level. To compress such rarified air with present day pumps would present technical difficulties. Moreover, compressing this thin air to a comfortable pressure level would produce a rather high temperature in the cabin, uncomfortable for the occupants. And finally, between 60,000 and 140,000 feet, the atmosphere is enriched by ozone, formed from oxygen under the influence of solar ultraviolet radiation. In a conventional pressure cabin, this highly active chemical substance would be concentrated to a sufficient density to cause an irritating effect upon the respiratory organs.

For all these reasons, the use of the ambient air above 70,000 to 80,000 feet to climatize the cabin, is out of the question. We must resort to another type of cabin, one that is independent of the outside atmosphere; a cabin that itself can take over the atmosphere's vital environmental functions by means of an artificially created and artificially controlled atmosphere. Such a device is the so-called "sealed cabin." What is a sealed cabin and how does it work?

A sealed cabin is a closed system in which the life sustaining components of the air are taken along from the start at the Earth's surface. During flight, the oxygen consumed by the occupants in the process of respiration, must be replaced, from tanks; carbon dioxide produced in the same process, must be removed. A comfortable barometric pressure must be maintained; and humidity, temperature and odors must be controlled.

In a sealed experimental chamber, such as that shown in this picture, now in use at the USAF School of Aviation Medicine, Randolph Field, Texas, we can study these various factors and can test the physical or chemical means of controlling them.

The situation in a sealed cabin craft is somewhat similar to that in a submarine. One difference, however, is that the submarine can use a schnorkel to refresh its ~~xix~~ inside air with the air above the water, while the sealed cabin craft is completely cut off from any life sustaining contact with the earth's atmosphere. The sealed cabin is - so-to-speak - a world all its own, a little earth with its own artificial atmosphere inside and a tiny population of only two, three or four. It has no altitude limitation whatever; it gives the green light into space. This cabin is, therefore, the type that will be built into future space ships. It is important, however, to keep in mind that such a space cabin is required even in the middle part of the stratosphere, as we have just learned. The necessity for such a cabin within our atmosphere is again an example for the occurrence of space equivalence above a certain atmospheric level.

The sealed cabin must not only provide an adequate climate for the crew, it must also take over fully the atmosphere's filter function concerning cosmic rays and solar ultraviolet radiation, above 120,000 feet. Cosmic rays are nuclei of atoms - of hydrogen, helium and even heavier atoms like iron that have been accelerated in electromagnetic fields between the galaxies to very high speed approaching that of light. They have, therefore, a tremenduous penetrating power. When they hit any matter like the atmosphere or metal or living tissue, they knock off electrons from the molecules or atoms lying in their pathway and produce a so-called ionization track. Or, they might hit the nucleus of a heavy atom of the material directly. In this cose, both disintegrate under the terrific impace in the form of an explosion Star. Such events always take place in our atmosphere between 60,000 and 120,000 feet. The collision products - neutrons, mesons and protons - penetrate down to the earth, sometimes in showers. These less powerful splinters of the primary cosmic rays are called secondary rays, to which we apparently have become accustomed. The possible biological effects of the primary cosmic rays as they are found in Space are presently being studied by the Space-Biological Laboratory at Hollomann AFB, New Mexico, in balloons carrying mice or hamsters in sealed gondolas. These balloons float for about 60 hours in altitudes up to 100,000 feet and are sometimes mistaken for the so-called "flying saucers." These cosmic ray studies are also carried out for the purpose of determining the best means for protection that could be applied to the sealed cabin craft.

Finally, the hull of the sealed cabin must replace the atmospheric protecting wall against meteorites. Most of the meteorites that produce the wonderful spectacle of a meteor or shooting star when plunging into the atmosphere, have an average size of a pea and a speed of 30 miles per second. For protection against these bullets from outer space, special meteor bumpers or screens have been suggested consisting of an outer layer of steel surrounding the hull, to absorb the shock of the colliding meteorite. The probability of a hit by a meteor, however, is rather remote - even beyond the 75 mile level of the rarified atmosphere and likewise in space. And if this really should happen and should cause a leak in the cabin, we know pretty well the medical implications of the resulting decompression of the cabin.

Actually, the earth itself is a giant spaceship with about 2½ billion occupants, moving at a speed of 18.6 miles per second in its orbit around the sun, through the vacuum of interplanetary space. The air on its surface is continuously regenerated by physical and biological processes resulting in a rather constant oxygen content of 21 volume percent to which we have become accustomed. The atmosphere is sealed off by the earth's gravitational pull, which prevents the air molecules from escaping into the surrounding vacuum of space. And what we must do if we leave this planetary mother spaceship is to just simulate in the sealed cabin craft, the life sustaining processes which the earth does for us on a gigantic scale.

There is one environmental factor, however, that can hardly be substituted in a space craft - the normal gravitational force of the earth, just mentioned. It is the force responsible for our weight.

On the ground, our body with all its functions is at all times and in all places subjected to this mechanical force to its full intensity. This is also true in a slow moving airplane because it is supported, dynamically, by the on-rushing air, just as much as it is supported statically by the solid surface of the ground. Now, in a horizontal flight, under the pull of the earth's gravity, the airplane follows a curved path, parallel to the curvature of the terrestrial sphere. As you know, centrifugal reactions caused by the inertia of the body, originate in any curve. In a horizontal flight which is actually a very flat curve at subsonic speed - i.e., speed below the speed of sound (760 mph), the centrifugal forces are minimal. In the supersonic range, however, these forces become more and more pronounced in such a way that they counteract the gravitational pull of the earth and partially substitute the mechanical support by the air. This results in the craft and the crew becoming lighter and both show the phenomenon of decreased weight or subgravity. For example, at 10,000 mph their respective weight is reduced to 60 percent of the normal.

Finally, the centrifugal forces become equal or balance the gravitational force of the Earth; then the moving vehicle becomes completely weightless. This state of zerogravity or weightlessness, of greatest interest from the medical point of view, is reached at a speed of 19,000 mph. In a horizontal flight, however, the state of weightlessness can not be obtained within the lower and middle zones of the atmosphere because air resistance would prevent the speed required. In addition, friction with the air molecules would produce an extremely high surface temperature on the hull of the craft - an effect certainly known to all of you as the "heat barrier" or "thermal barrier." At about a 120 mile altitude, however, the atmosphere is too thin to offer any drag or resistance or to produce any friction heat at any speed. At and above this level which is correspondingly called the mechanical border and the thermodynamical border of the atmosphere, we can produce weightlessness for any length of time, and frictionless movement, the same as in free interplanetary space. This, therefore, is the altitude where the nearest orbit of an artificial satellite is conceivable.

The atmosphere, above 120 miles, for a fast moving craft, is equivalent to the vacuum of interplanetary space in almost every respect. But, as you will recall, space equivalence of the atmosphere is found even within the stratosphere with regard to oxygen, air pressure, the necessity of the sealed cabin, radiations, and so forth. For the flier, the area between 50,000 feet and 120 miles can be considered as partially space equivalent and the area above 120 miles is distinguished by total space equivalence. The atmosphere beyond 120 miles is no more recognizable from the standpoint of manned flight. In terms of the meteorologist, however, it ends at an altitude of 600 miles.

This being so, we now have the answer to the question of where we stand today in the development of space flight.

After manned rocket powered planes have flown to 90,000 feet, we are justified in saying that we are now in the space equivalent phase of manned flight. Animal carrying rockets have reached nearly 100 miles, and a two-stage rocket, the WAC Corporal mounted on a V-2, with an altitude record of 250 miles, has penetrated deep into the thin atmospheric regions of total space equivalence. We are indeed at the threshold of space flight.

The study of speed also reveals the nature of the things to come. The breaking of the sound barrier is now past history - following Jack Jeager's 1950 record flying faster than the speed of sound. The record now stands beyond twice the speed of sound, or Mach 2. In manned flight we are in the supersonic speed range. Rockets, such as the V-2 and Viking, fly with hypersonic speed. Hypersonic is the term used for higher Mach numbers, those beyond 5 or more. At these great speeds not only shock waves and high hull temperatures are produced, but also electric phenomenon in the form of ionization of the boundary layers of the air around the rocket.

At 19,900 mph or 5 mi per sec - about 25 times the speed of sound - we will have reached the orbital or circular velocity, the speed required for the establishment of an artificial satellite, as already mentioned. When a speed of 7 mi per sec is reached, the vehicle will escape in a parabolic curve into interplanetary space. This speed level is called the escape velocity. At present, as this figure shows, with a two stage rocket, the Wac Corporal mounted on a V-2, we have reached 30 percent of the orbital velocity and 20 percent of the escape velocity. This then is where we stand today with regard to speed.

The invention of the rocket is certainly an achievement of revolutionary significance. The full exploitation of this method of propulsion, however, will probably take a step by step evolution. When we consider the atmospheric environment with its space equivalent qualities, plus the characteristic speed levels that we have just discussed, and combine them with distances that are or will eventually be covered on or away from the earth, we get a picture that looks somewhat like the one that follows.

Starting with present-day long distance flights; the propellor and jet driven planes carry us at subsonic speed, under normal gravitational conditions, through the lower regions of the atmosphere in pressurized cabins, from one place on the globe to another distant place on the globe, across a number of time zones and/or across zones of different seasons, in a single day. These are global flights. This epoch in flying began when Charles Lindberg first crossed the Atlantic in 1926.

We are now on the threshold of the next stage. In that epoch, rocket powered planes will take us at supersonic speed or even at hypersonic speed under slightly subgravitational conditions, in a sealed cabin through the space equivalent regions of the atmosphere, from one point on the globe to another even more distant point on the globe in a matter of a few hours. We stay on the globe but fly under space equivalent conditions. With regard to gravitation, the craft flies partially under airplane conditions and partially, however, under ballistic conditions like a bullet or meteorite. These long distance flights will fall into the category of global space flight. The forerunners of this long distance global space flight are seen in the short distance, short time flights of rocket powered planes and unmanned rockets of today. They can be termed local space flights.

As soon as the circular velocity (5 mi/sec) has been reached, flights of long duration around the globe in a satellite orbit under conditions of zero gravity and in an environment equivalent to space, will be possible. But these craft will still operate within the gravitational pull of the earth and will remain within the earth's vicinity. This eventual stage may be called <u>circumglobal space flight</u>.

The final stage will follow after the escape velocity (7 mi/sec) has been reached. When the day comes that a manned rocket will attain this speed and move freely in space with the characteristics of a small celestial body such as an asteroid, then we will have arrived at interplanetary space flight or what can then be called "space travel."

I believe this classification, based on a step by step approach to the possibilities of rocket-powered flight, will give you a realistic picture of where we stand today and of what we may expect in the future. At present we are actually in the first phase of space flight, namely, <u>global space flight.</u> Solution of the medical problems in this stage is, therefore, of immediate concern, but basically they are the same as those encountered in an artificial ~~xx~~ satellite or in the final stage of interplanetary space travel.

The essential difference is the time factor in the duration of the flight. In conclusion, I would like to state that the medical problems encountered in all the aforementioned stages of space flight do not seem to be insurmountable, unless there are still some factors in space completely unknown, which is unlikely.

Now, you might ask "All right, space flight does seem to be in the offing, but what is the good of it?" Or, you might also add "Isn't it a waste of money?" This, briefly, may be the answer:

First, in flights outside the atmosphere in the form of what we have described as global space flights, we are not subjected to the adverse weather conditions found in the troposphere such as fog, clouds, electrical storms, and other kinds of turbulence, except during the brief time necessary for takeoff and landing.

From the strategic point of view, global space flights are better protected from enemy action by the extreme height and supersonic and hypersonic speed of the craft. Both of these factors also offer a strategic advantage in the element of surprise.

From the scientific point of view, space flight of all varieties, presents an unique opportunity to study the globe as a whole, with regard to its surface features, its magnetic field, and especially the overall pattern of the meteorological processes in its atmosphere together with some extraterrestrial factors that might influence these processes, such as micrometeorites.

Furthermore, space flight would enable us to investigate the nature of free space on the spot, and even permit the telescopic studies of other planets undisturbed by light absorption, light scattering, and turbulence in the air.

The rocket - like the V-2, Aerobee, and Viking - has already firmly established itself today as a valuable tool of research in the upper atmosphere and has contributed greatly to our knowledge about the chemistry and radiation pheonomena in altitudes never reached before. The chemical and physical conditions in the upper atmosphere determine, to a great extent, the dynamic and meteorological processes in the lower zones of the atmosphere, in other words, the weather.

We too, in Space Medicine, use rocket flights to study, for instance, the effect of weightlessness on animals. After an initial period of acceleration the rocket follows an elliptic curve. During this time in the zones of rarified air the rocket and the occupants are weightless. I would like to demonstrate this to you in a short film made at Hollomann Air Force Base, which I will now show:

Gentlemen: I hope you will agree that space flight in its varities is of immense practical and theoretical importance to us. It is the project of grandeur of this century, that requires the enthusiastic cooperation of the flier, the engineer, and the medical doctor.

Most especially, it is a challenge to the younger generation as represented here by you.

Gunter + Eglen

Given to U.S. West Point Cadets, July. 1955

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