SPACE EQUIVALENCE WITHIN EARTH'S ATMOSPHERE*

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For the first fifty years of its existence, human flight has been confined to the Earth's atmosphere. With the invention of the rocket, however, an engine that based on Newton's law of action and reaction does not need the presence of air as a medium of support, this earthbound restriction is gradually losing its hold; in fact, the rocket offers even the possibility of penetrating the vast areas beyond the atmosphere, namely, interplanetary space. And now, space flight, flights to the Moon or Mars, have become favorite topics of discussion in publications, on the radio and on television. We do not, however, even need to go that far. There are regions that show - from the standpoint of human flight - the characteristics of free space and yet still belong to our atmosphere. These space equivalent regions of the atmosphere are today within the reach of the present rocket powered planes and rockets. They are, therefore, of immediate interest to us. Moreover, the medical problems involved in flights through this portion of the atmosphere reveal a step by step transition from atmospheric flight to actual space flight.

This revolutionary development in human flight calls for new concepts for a revision of conventional definitions, and for an extension of our aeromedical thinking along the lines of other scientific fields such as astronomy and astrophysics. The establishment of a new branch of Aviation Medicine, namely, Space Medicine, was a logical outcome of this development.

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It is an honor and a great pleasure to discuss the medical problems involved in the atmospheric regions of space equivalence before this group of educators from the medical schools participating in the program of the Medical Education for National Defense.

In order to clarify the meaning of space equivalence, we should first know what true space conditions actually are. Space is not an absolute or perfect vacuum; it still contains the so-called interstellar or interplanetary matter. The density of this interplanetary matter is extremely low. The number of particles is about 1 per cm^3. This is about 100,000 times less than in the best vacuum technically obtainable on earth. Most of these particles consist of hydrogen, as shown in Table 1. In addition, space is criss-crossed by high speed particles of cosmic matter such as meteorites and micrometeorites. It is also traversed by corpuscular and electromagnetic radiation of solar and cosmic origin. Such are the particles of matter and quanta of energy in the environment of a nothing.

In contrast, the atmosphere near the earth's surface has a particle density of 10^{19} per cm^3. With increasing altitude it decreases almost exponentially; so does the air pressure. Parallel thereto, the free pathway between the particles increases. Finally, the free path becomes so large that collisions are very rare, allowing the particles to move freely with the velocities attained at their last collision in elliptic, parabolic, and hyperbolic trajectories; those of elliptic orbits fall back again under the pull of the earth's gravity, the others - mainly hydrogen and helium - escape into space.

Only so long as collisions between particles continue to occur, can the atmosphere be considered a material continuum. The collision limit or escapt level is found at about 600 miles or 1000 km above the earth's surface.

Therefore, this level is the border of the atmosphere with regard to its ~~geographic~~ [vertical] material extension. [redacted] in terms of ~~the astronomer~~ [Astrophysics], or, the ~~astronomical~~ [materials] border of the atmosphere. Above this level we observe a kind of spray zone formed by the free moving air particles. This fringe zone, called the exosphere, gradually thins out into the near vacuum of space. Such is the picture of the atmosphere in its entire vertical extension.

Now, we can proceed to the nucleus of our discussion - namely to that area where atmosphere and space overlap. From the standpoint of manned flight, it is not the material extension of the atmosphere that counts, rather it is the cessation of the functions that the atmosphere offers for manned flight. These functions are manifold; but they do not terminate at the astronomical border at 600 miles, instead, they come to an end much lower and at different altitudes, some even well within the stratosphere. The levels where the various atmospheric functions cease have been designated the functional borders of the atmosphere. This is a very useful concept. At these functional borders and above them, we encounter space-like or space equivalent conditions with regard to the function in question. The term "space equivalence" within the atmosphere is perhaps even more useful in research and teaching. First, it is a broader concept. We can associate it with certain atmospheric levels that are identical with the functional borders. In addition, we can apply it to the entire atmospheric region above the functional borders. Further, it can be applied to conditions which are not confined to a specific level or region such as the zero-gravity state. And finally, because the term equivalent is found in many languages, it is well understood internationally.

The functions of the atmosphere, by and large, can be divided into three principal categories: climatic functions, filter functions regarding extraterrestrial factors, and finally, aerodynamic functions.

By subdividing them more into detail and contrasting them with the conditions to be found in space, we arrive at the following ten points:

1. The atmosphere contains a rather high concentration of oxygen needed for respiration - in Space there is no oxygen;

2. The atmosphere exerts upon us sufficient barometric pressure to maintain 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 no ambient air is available;

4. In the lower atmospheric zones we are protected from the too intensive cosmic radiation by the earth's filter function - in Space no such natural protection can be expected;

5. This same situation holds true for the ultraviolet part of the solar spectrum;

6. The protective function of the atmosphere also applies to the meteorites.

7. In the atmosphere, light is scattered by the air molecules, producing the so-called skylight - ~~in~~ Space, without skylight, is ~~permanently~~ in a permanent state of darkness.

8. The atmosphere transmits sound waves - in Space there is no medium for sound propagation and for shock waves; space is completely silent and calm.

9. The atmosphere provides mechanical support or lift to a moving craft - in space no such support can be expected;

10. The atmosphere with its tightly packed molecules holds, conducts and transfers heat - in space, the carrier and transmitter of heat is exclusively solar radiation.

Now, lets examine where these ten functions of the atmosphere cease, and where the characteristics of space begins

1) First, the oxygen problem. At what altitude does the atmospheric function of supplying us with this vital bioelement come to an end? To answer this question we must take a look at the airbody that is interposed between the external atmosphere and the milieu interior of our body, namely, the alveolar air.

The CO_2 pressure in the alveolar air - as you know - amounts to from 35 to 40 mm Hg. The alveolar water vapor exhibits a pressure of 47 mm Hg at normal body temperature. Their sum of 80 to 87 mm Hg is - to some extent - constant. For this reason - with increasing altitude - alveolar oxygen pressure falls more quickly than that of the outer atmosphere. As soon as the total air pressure decreases to about 80-87 mm Hg., the influx of oxygen into the alveoli from outside drops to zero - because the alveoli are already occupied by carbon dioxide and water vapor, both issuing from within the body itself. The air pressure of 87 mm Hg. corresponds to an altitude of about 50,000 feet.

From the space medical point of view, this is a decisive point or level. It is the physiological oxygen dividing line concerning atmosphere and space. This statement is supported by the behavior of the time of useful consciousness after an explosive decompression within this area of altitude. This important time reaches its minimum value of about 15 seconds at 50,000 feet, according to Armstrong, Clamann, Luft, and Sweeney. There is no reason to assume that the time of useful consciousness will change at still higher altitudes, insofar as oxygen as the sole cause is concerned.

A similar observation was made in experiments on animals with regard to the duration of respiration and the survival time after explosive decompression by S. Gelvan and U. C. Lutz.

From all this we can conclude that above 50,000 feet we are beyond the atmospheric range that supports respiration. Physiologically, we have reached the <u>zero-point in the oxygen pressure of the atmosphere</u>, even though physically, oxygen is still found there. So far as oxygen is concerned, we encounter the same physiological situation as in free space. Hence, it is here that we meet the first of the most important functional borders of the atmosphere or space-equivalent levels within the atmosphere.

At this point I would like to make a pertinent remark with regard to terminology. Formerly, oxygen deficiency was generally referred to as "anoxia." For the past 20 years the term "hypoxia" has been preferred because it is more to the point. However, confusion still exists in the literature and textbooks of physiology and medicine. From the space medical point of view the term "anoxia" now has a new place and can be used in its true meaning - no oxygen at all. Below 50,000 feet we may speak of hypoxia - above 50,000 feet we are justified in speaking of anoxia.

A comparison with an oxidation process in the inorganic world might be in order here. This Figure shows a series of pictures on the behavior of a candle flame subjected to various atmospheric pressures when reduced, in each case, by one tenth of an atmosphere. Below 1/10th of an atmosphere, that means below an oxygen pressure of about 15 mm Hg., the candle light goes out. This is the ~~first border of the atmosphere~~ altitude limit for fire within the atmosphere.

2) Another spacelike condition is encountered at a slightly higher altitude. This condition is related to the total pressure of the air and its bearing upon the change of state from liquid to vapor. Any fluid exerts a certain vapor pressure above its surface. Its maximum or saturated vapor pressure depends on the fluid's temperature. By heating the fluid the vapor pressure increases to the point where it finally equals the barometric pressure above the fluid.

At this point the fluid boils. The same can be achieved in a fluid of a certain constant temperature by decreasing the barometric pressure down to the vapor pressure of that fluid. The water vapor pressure of our body fluids at the normal body temperature of 98.6°F is 47 mm Hg., a figure already mentioned in the discussion of the alveolar air. We can expect therefore, that as soon as the barometric pressure drops to 47 mm Hg., or below, our body fluids will boil. Quantitative experiments on warm-blooded animals in a low pressure chamber, carried out as early as 1935 by H. G. Armstrong, showed that they do. This boiling effect is first manifested by the appearance of gas bubbles in the superficial mucous membrane of organs such as the mouth, and on the conjunctiva of the eye. A little later, bubbles form in the blood, depending upon the various pressures in the vascular system. The intrapleural spaces are filled with vapor - a phenomenon which was designated a vapothorax by F. A. Hitchcock. The entire skin swells in what we might call a vapor-emphysema, or emphysema vaporosum, or it may even form large blisters, bullae vaporosae, a process which can also be called "epidermolysis e vacuo." And there are still a number of questions open in this field of vacuum pathology.

An air pressure of 47 mm Hg. is found at an altitude of 63,000 feet, above this altitude, then, we lose the vitally important protection of air pressure against boiling, just as we were surrounded by no atmosphere at all. Physiologically, we have reached the <u>zero-point of air pressure</u> even though there is some pressure left. This is the second functional border of the atmosphere or space equivalent level.

At this point I would again like to make a terminological remark. "Boiling" must be considered here in its true scientific sense. In every day life, boiling is generally referred to higher temperatures, around 212°F, and is identified with one of the methods of preparing food by boiling, namely, cooking.

This includes coagulation of the proteins contained in the cellular plasma and intercellular fluids. The lowest temperature at which coagulation of proteins takes place is at a temperature around 55°C. At this temperature water boils at a pressure of 110 mm Hg. or at an altitude of 45,000 feet. Below this pressure, or above this altitude, boiling is not associated with protein coagulation. Since boiling, however, is generally associated with cooking, it is not the proper term for low-pressure low-temperature vaporization of the body fluids as it is encountered in the altitude above 63,000 feet. A better term is needed, one that reflects the true nature of boiling in high altitude and has not such a deterrent effect psychologically. So much for this terminology.

Both of the space equivalent conditions just discussed are impressive enough to convince us that we have entered a strange and completely novel environment. Here we face the anoxic phase and the vapor phase of high altitude effect. These two facts justify the statement that a flyer entering the region above 63,000 feet must be considered from a pure physiological point of view in space, for the physiological effects upon his body are the same that he would find in the near vacuum between the planets.

Indeed, physiologically, the air pressure below the vapor pressure of the body fluids must be considered a vacuum, despite the fact that at the air pressure of 47 mm Hg., 5.7×10^{17} molecules are still found at 0°C. According to conventional definition the technical vacuum begins below 1 mm Hg. At this pressure 1 cm^3 of air contains 3.5×10^{16} molecules. The number of molecules in the best vacuum obtainable on earth (10^{-8}) mm Hg. is of the order of 10^6 per/cm^3. In free interplanetary space, only 1 particle is found in 1 cm^3. The pressure of this nearly vacuum is technically not measureable. To this near vacuum of interplanetary space, the air pressure below 47 mm Hg. is physiologically equivalent, which means that at this pressure, physiologically the vacuum begins.

3) Necessity of a sealed cabin. The pressurized cabin was introduced in the mid-thirties as a protective measure against the effects of severely decreased oxygen and air pressure. In such pressurized planes, the cabin air is derived from the ambient atmosphere. This possibility, however, is limited. The limit is reached at about 70,000 to 80,000 feet for the following reasons:

1. Technical: The air density at this altitude is about 1/25th of that at sea level. Because of this low density, compression of the ambient air to physiological levels would require very bulky compressors, technically prohibitive.

2. Thermodynamical: To compress this thin air to physiological levels would also result in the production of intolerable heat for the occupants (about 400°C).

3. Toxicological: The zone between 60,000 and 140,000 feet is enriched by ozone. At its peak (around 75,000 feet) the ozone concentration is about 1 part per million parts of weight. Compressed to normal air pressure, the cabin's air may attain an O_3 concentration that is above the threshold of toxicity.

For all these reasons, above a certain altitude level, the use of ambient air as a source of breathing air for the crew, is out of the question. We must resort to a new type of cabin, the sealed cabin.

The sealed cabin is a hermetically closed ecological system, in which the life sustaining components of the air must be taken along from the start. The oxygen consumed must be replaced from tanks. The expired carbon dioxide must be removed. The same is true for other physiologically originated gases, such as water vapor, methane, and hydrogen sulphide.

While the altitude limit for the use of oxygen equipment lies at about 40,000 feet, for the pressurized cabin at about 80,000 feet, the sealed cabin has, theoretically, no limitation on altitude whatever. It gives us the green light into Space.

The altitude at which a hermetic cabin becomes necessary represents another space-equivalent condition, from a biological point of view as well as from a technical one. Above this level the cabin has no life-sustaining contact with the earth's atmosphere. It is a world all its own; a little earth, a terrella, with its own atmosphere. It is the type of cabin that will be built into future spaceships. But it is important to keep in mind, that such a "space cabin" is required, even at an altitude level well within the atmosphere.

The USAF School of Aviation Medicine at Randolph Field, Texas, now has an experimental sealed chamber in which we can study the various bioclimatic factors involved and the best means to control these factors.

The space equivalent conditions which we have discussed so far are brought about by the loss of genuine properties of the earth's atmosphere. However, with increasing altitude extraterrestrial factors enter the picture, to a greater extent. Finally, they create space-equivalent conditions of their own, still within the atmosphere as it is astronomically defined. This group of space equivalent conditions is related to the filter function of the atmosphere.

This atmospheric function is of greatest import with regard to radiation. Until now, aviation medicine has had no special reason to be concerned with radiation of natural source. However, just as soon as planes exceed heights where the radiation filter function of the atmosphere vanishes, this will change. We must then reckon with radiations of cosmic and solar origin in their original form and intensity as they are found in the earth's orbit in interplanetary space.

4) Cosmic rays. Cosmic rays in their "space form" consist of up to 79 percent of protons or hydrogen nuclei and 20 percent of alpha particles or helium nuclei. Since 1948 we have known that the remaining percent is composed of the nuclei of heavier atoms. Small in numbers, these heavy primaries are extremely powerful. The table of Dr. Hoyle, British astronomer, gives you an idea about

their motion energy. Based on the motion energy of the molecules of the human body as a unit, the motion energy of particles in the interior of the Sun is 10,000 times higher,that in an A bomb, 100,000 times higher, and that of cosmic rays about 1 billion times as high. They have, therefore, an extremely high penetrating power. They have probably attained this high energy by acceleration in magnetic fields between the galaxies and interstellar clouds. When the primary cosmic rays enter the atmosphere, from a certain density level on, they lose their original powerful form in ionizations of air molecules and atoms and in collisions with the nuclei of atmos. This process of absorption takes place between 120,000 and 60,000 feet. The ionization and collision products: protons, electrons, neutrons, mesons, and gamma rays, rain down, sometimes in showers, through the lower layers of the atmosphere. These secondary rays, which were discovered by V. Hess, 1908, during balloon ascents, are less powerful than the primaries but powerful enough to penetrate several hundred feet into the water. So, at sea level and up to 60,000 feet we are exposed only to these secondary and teritary cosmic rays; our body is hit by these splinters of the primaries at a rate of about 3 per square area and minute. Apparently we are accustomed to these small calibric cosmic shots. Above 120,000 feet, however, we will be exposed to the more powerful bombardment of the original primaries. Here, we are beyond the protecting shield of the atmosphere, as in space, or as we would be on the moon which has no atmosphere. This is the fourth space equivalent level within the atmosphere or the first with regard to the atmospheric filter function.

Now, two modifications - with regard to the occurrence of primary cosmic rays - must be noted. One is the fact that in the vicinity of the earth, we are shielded from one-half of the rays by the bulk of the earth itself. Because of this shadow effect upon cosmic rays we may refer to this situation as a semi-space equivalent condition.

The other modificationarises from the earth's magnetic field. All particles below a certain magnetic rigidity are deflected and bounced back into space by the geo-magnetic field, if they approach the earth in the neighborhood of the magnetic equator--that is to say, between 50° South latitude and 50° North. This band of relatively low radiation intensity, 100 degrees of latitude wide at the base, extends as far as the orbit of the Moon. So much for the localization of the space equivalent atmospheric regions concerning cos mic rays. Dr. Schaefer, who was the first to bring the biological significance of the heavy primary into the focus of medical interest, will discuss them more in detail especially from the standpoint of biophysics.

Of some biological interest also is the erythema or sunburn producing ultraviolet of solar radiation. Its band lies between 2100 and 3000 Å. Most of these rays are absorbed by the ozone of the atmosphere. We are, therefore, protected against their effects at sea level and moderate altitudes. We live in the shadow of ozone. The atmospheric ozone is concentrated mainly in the area of 70,000 to 140,000 feet (ozonosphere). This means that above the 140,000 foot level we are beyond the ozonospheric umbrella of the atmosphere, which means that we are exposed to the full force of ultraviolet. Again space-like conditions within the atmosphere with regard to this factor. They should, however, present no serious problem, since the hull of the ship protects the crew sufficiently; it might perhaps alter the transparency of the windows, which would in turn entail optical problems.

5) <u>Scattering of Light</u>. This brings us to the visible part of the electromagnetic spectrum of solar radiation. An important factor in atmospheric optics is the scattering of light by the air molecules. This scattering effect of the atmosphere produces the so-called skylight; and because the short wave part of the visible spectrum is especially affected by this process, the sky appears blue to us. With increasing rarification of the air molecules in higher altitudes, however, scattering of light decreases more and more and the blue sky gradually turns into the mysterious darkness of space. This optical space equivalent condition is reached in the area of 80 miles.

Essentially, it is the lack of scattering that makes space optics so different from atmospheric optics. In the lower atmosphere, during daytime, the stars and moon fade into invisibility in the blue diffuse skylight. In space, with the absence of skylight, the stars are visible at all times and when its position allows, the moon can be seen in full brilliance with the Sun. Because of the lack of skylight, the sky brightness or luminance of the sky is about 10 millilambert as compared with 500 millilambert the average value at sea level. Since there is no interference with an atmosphere by absorption and scattering, the solar illumination in space is about 13,500 foot candles as compared with 11,800 foot candles at sea level. This means that against a low background of field brightness, any object illuminated by the sun appears extremely bright. Light and shadow dominate the scenery comparable to the light and shadow effects like those used on the stage by the magician. This photoscotic condition which is encountered in full display at about 80 mile altitude, poses interesting visual problems in the field of contrast vision and retinal adaptation.

6) Propagation of Sound. At about this same altitude, propagation of sound becomes impossible. Sound propagation requires a certain density of the air. But as soon as the free pathway of air molebules is in the order of the wave length of sound, transmission of sound ceases. First, in lower atmospheric levels the higher tones are affected; finally, as altitude increases, the lower tones also disappear. The region where this occurs lies between 50 to 100 miles. On the basis of transmissibility of the air for sound we can divide the atmosphere into three zones; the accoustic zone from 50 to 100 miles; and the anacoustic zone above 100 miles. Here the silence of space begins. In this thin atmospheric medium no shock waves can be produced at any speed; therefore there is no sound barrier and the unit of "Mach" number becomes meaningless.

7) Meteorites The most spectacular of extraterrestrial factors are meteorites. Between 25 and 75 miles above the earth, most of these meteors are burned out by friction with the atmosphere. Above 75 miles a rocket ship is beyond the "meteor safe wall" of the atmosphere, unprotected as in space.

Here again variations of this space-equivalent condition must be considered. One is caused by the fact that, in the viainity of the Earth, we are shielded from one-half the meteors by the bulk of the earth itself. This situation is again a semi-equivalent space condition. The second variation arises from the speed of the Earth. Our globe revolves around the sun at a speed of 18.6 miles per second. Relative to the earth, therefore, the velocity of meteors which strike the earth from the front, in a head-on collision, is greater than the speed of those which overtake the earth from the rear.

Be that as it may, the likelihood of colliding with a meteorite, fortunately, is remote, even outside the atmosphere - according to most astronomers.

All of the problems which I have enumerated so far, would arise if we consider a vehicle in this environment at rest or floating - if this were possible. The respective space equivalent conditions include their modifications are more or less topographically or locally fixed at certain altitude levels, conditioned by the milieu as such, and therefore may be called local space equivalent conditions.

One important space condition occurs within the atmosphere, however, as a direct result of the vehicle's own movement. This is the phenomenon of weightlessness, or the gravity-free state, a problem about which most confusion is found, as expressed in the question, where do we leave the gravitational field of the earth and when; the answer is nowhere and never.

It is true that the force of gravity decreases with the inverse square of the distance from the earth's center. At a height of 4,000 miles above the earth's surface, or twice the earth's radius from the earth's center, it is only 1/4th of what it is on the ground; at 8,000 miles it is only 1/9th, and so on. At a distance of 36,000 miles it is reduced to a mere 1/100. The near gravity-free state at this altitude is indeed a local condition, but it could only be valid for a supported body - for example, one lying on a tower 36,000 miles high above one of the earth's poles - if such a thing were conceivable.

With a vehicle in flight, however, the situation is quite different. Subgravity and zero gravity can be produced at any height. The effect is produced by the motion of the vehicle itself.

The solution of the medical problems involves physiology, biophysics, biochemistry, and various specialties of medicine. Some of the problems are old, but they appear in a new light; others, however, are completely novel. In the lectures on physiology and biophysics special emphasis must be given to the extremes in decreased oxygen pressure and air pressure and to the climatization of a closed ecological system. In the biochemistry of the human body, the atomic composition rather than the molecular composition is of special interest concerning the possible star production by cosmic ray particles. Solar energy, its life sustaining and life endangering properties, has moved into the focus of our attention. With the occurrence of the gravity free state, the geometry of conics or conic sections such as circular, eliptic and parabolic sections enters the picture of the physiology of movement. For the first time experience in practice that mass is a constant intrinsic property of a material body, in contrast to weight and inertia which - depending upon an external force, namely acceleration - are extrinsic properties of a material body. The function of the gravi-receptors such as the otoliths, offers new interesting aspects with regard to the Weber-Fechners law. The function of the peripheral gravi-receptors like those of the pressure sense of skin, the muscle spincles and the Pacinian corpuscles in the connective tissue under various gravitational conditions is a problem that should interest the physiologist and anatomist alike. These are only some of the subject matters, that demand more space on the lecture programs at the Medical Schools.

After the war some people thought Aviation Medicine was only a matter of routine; that there was nothing new for research and teaching. However, the rocket has opened a new frontier, now reaching far into the upper atmosphere. It has also opened a new frontier in medical science. The advancement that will be made on this frontier will determine the progress on the other. The space

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equivalent phase of human flight is only the foreground of this vertical frontier. The medical problems involved, however, are basically the same as in all further stages of human flight. This fact accentuates the importance of the study of the medical implications in space equivalent flights.

The main characteristic features of this stage of human flight are: the space equivalent zones of the atmosphere, a sealed cabin, supersonic and even hypersonic speed, flight by propulsion and flight by inertia, airplane status of the vehicle and also projectile status and finally, high accelerations, subgravity and zero gravity.

In order to complete the picture I would like to conclude with a few remarks about the possible development of human flight beyohd the space equivalent level. This development will be determined, mainly, by the speed that will be attained. As previously mentioned, at 5 mps or 18,000 mph the so-called orbital or circular velocity is reached: the speed which will enable a craft to circle around the earth in a fixed circular orbit for a considerable length of time. In this stage, flight by propulsion is completely replaced by flight by inertia. This, however, is not possible below the astronautical border of 120 miles. Above this border, however, the vehicle attains satellite status. As long as these orbits do not lie beyond 600 miles, they still remain under the space equivalent conditions of the atmosphere. But in this pseudoatmosphere, as we have chose to call it, the conditions are practically the same as in free space. And the vehicle will still remain under the gravitational control of the earth and operate within the earth vicinity. This eventual stage may be called circumplanetary or more specifically circumterrestrial space flight. The small artificial satellite, that will be launched in 1957 or 1958, as announced recently, is the first step in this direction.

When a speed of 7 mps or 25,000 mph, the so-called escape velocity is reached, the vehicle will break away from the gravitational control of the earth and will escape into interplanetary space. With this final stage we will have arrived at interplanetary space flight or what can then be called - interplanetary space travel.

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. A three stage rocket may bring in the remaining percent.

This step by step approach to the possibilities of rocket powered flight by human beings is perhaps more stimulating, and more fruitful for research and development, than the all or nothing attitude displayed by those who gaze constantly upon remote celestial bodies like the Moon or Mars in a kind of space-fascination. The psychological power of attraction of these objects as the final goal, however, must not be underestimated. They are indeed a valuable background stimulus for our efforts toward the advancement of human flight.

This classification gives us, I believe, a clearly defined and realistic picture of the stage at which we stand today and of the possibilities we may expect in the future. At present we are actually in the first phase of space flight, namely, global space equivalent flight. Solution of the medical problems in this stage is, therefore, of immediate concern to the physiologist, the gm engineer, and the flyer.