Man's Flight Into Space

By

James G. Gaume, M.D.
Department of Space Medicine
School of Aviation Medicine USAF
Randolph Air Force Base, Texas

Since man first looked upon the Moon, and discovered the existence of other planets in the heavens, he has dreamed of traveling one day to those celestial bodies, to explore them and to satisfy his curiosity concerning the unknown. Because of his inability to transport himself physically to the Moon or the planets, man devised a means of partially satisfying his curiosity by constructing telescopes through which he could explore them visually. The development of other instruments has enabled him to gather further information about the sun and planets with regard to their composition. Through the centuries, he has improved these devices to ever greater perfection, and has discovered that those tiny points of light in the night sky, which he had called stars, are actually suns similar to his own sun, but beyond his own solar system. These and other discoveries have stimulated man's dreams of actual space exploration. Today, space operations within our own solar system are rapidly becoming a reality. Indeed, it has been said that man is already flying in space.

If this be so, it immediately becomes obvious that a somewhat new definition of space is necessary. Space to the astronomer begins at the upper physical border of the atmosphere, or in the area of 600 miles from the Earth. To one dealing with the human factors of flight, space may be defined as that area which lies beyond the physiologically and physically effective portion of the atmosphere.

According to the latter definition, man is <u>already</u> flying in space. This statement can be clarified by presenting to you the concept of "Space Equivalence Within the Atmosphere" - a concept evolved by Dr. Hubertus Strughold, Chief of the Department of Space Medicine at the School of Aviation Medicine. He states that within the physical atmosphere, at various levels, occurs the loss of all the functions of the atmosphere, insofar as man and aerodynamic flight are concerned. The first function is lost at 52,000 feet or about ten miles, where the partial pressure of oxygen in the air is so low that it is prevented from entering the lungs, by the equal pressure of water vapor in the lungs. Even at slightly lower altitudes there is insufficient oxygen to sustain life, albeit absorbed from the air.

At 63,000 feet, the still lower barometric pressure is unable to keep body fluids in the liquid state, and the fluids vaporize as does boiling water, forming bubbles even at body temperature. These bubbles can snuff out human life in a few seconds. The new term -EBULLISM- has been given to this phenomenon, to replace the term "boiling of the blood" which connotes the application of heat.

These two, the oxygen and pressure borders, are physiological functional borders of the atmosphere. According to a physiological definition then, space begins at a level of 52,000 feet or about ten miles.

There are other physical functional borders which are reached at various higher altitudes. Thus, as the barometric pressure decreases with ascent, the air density at 70-80,000 feet is so low that we are no longer able to use ambient air to pressurize the cabin of a craft. A sealed cabin must then be used above this level for the following reasons:

1. At 80,000 feet air density is only 1/30th the air density at sea level. To compress it to acceptable levels would require equipment that would be prohibitive in size and weight.

2. If it were feasible to use ambient air, its compression would elevate the temperature of the cabin well beyond human tolerance, and would require a larger cooling system, again increasing the weight penalty.

3. At this same altitude the air has a high ozone content (6 ppm) produced by the action of ultra violet radiation upon atmospheric oxygen. This concentration is quite toxic to humans, and destructive to equipment, especially rubber and plastics. With compression adequate for physiological function 6 ppm would be increased to 60-80 ppm and would necessitate a device to destroy ozone.

4. In travel beyond the effective atmosphere, the ship will pass through the useable portion of the air with such speed that there would be very little time for outside air to be used for cabin pressurization. In less than two minutes it would be above 80,000 feet.

For these reasons one can readily see that a sealed cabin will be absolutely necessary in all forms of space operations.

Under physical borders can be included also the protective functions of the atmosphere. Factors which arise from beyond the atmosphere, but which are found within the atmosphere are solar radiation, meteorites, and cosmic radiation. At 120,000 feet primary cosmic rays begin to collide with the air molecules, causing them to explode into a shower of secondary radiation particles. These in turn strike other air molecules and the process is repeated, with an accompanying loss of energy of the particles with each successive collision. (Figure 1). The air attenuates the energy of primary cosmic rays and thus protects us from their potentially harmful effects.

At 140,000 feet the ultraviolet of solar radiation begins to react with oxygen, producing ozone. The maximum ozone concentration is in the region of 70,000 feet and becomes less at lower levels.

At about 75 miles (400,000 feet) meteors entering the atmosphere begin to heat up from friction with the air and most of them burn up completely before reaching the ground. Without the air envelope, we would be under continual bombardment by meteors, as is the surface of the moon.

In the thinning atmosphere above 400,000 feet (75 miles) sound audible to the human ear will no longer be transmitted, because audible sound is transmitted poorly in less dense media. Above this level the mean molecular pathway of the air molecules between collisions becomes greater than the wave lengths of audible sound. The higher frequencies with shorter wave lengths will disappear first, followed by the lower frequencies. This results in the absolute silence of space.

The same thinning of the atmosphere eliminates its capacity to scatter visible light. The blue color of our sky is caused by the scattering of visible light. So, at 80-100 miles the sky is black, with the sun, the stars, and moon all visible at the same time.

The last physical functional border lies at about 120 miles. Above this point, a craft moving at any speed no longer obtains "support" from the air and there is no longer friction heat or its transfer to the interior of the vehicle. Above 120 miles solar infra-red radiation is the most important source of heat with which we must contend.

As you can readily see, the conditions of space are encountered, not all at once, but in a stepwise fashion, beginning as low as ten miles and ending at 120 miles. (Figure 2) This is the area of partial space equivalence. Between 120 and 600 miles, although still within the physical limits of the atmosphere, lies the area of total space equivalence.

Near the end of World War II, jet planes were introduced over Europe by the German Air Force. The jet represented the first application, in aviation, of the reaction motor, which makes use of Newton's third law of motion. The law states that for every action there is an equal and opposite reaction. The jet engine is the transition device between the piston engine and the rocket engine. (Figure 3) The jet engine depends on the ambient air for oxygen necessary for combustion of the fuel. The rocket carries its own supply of oxygen, as well as its fuel, and is completely independent of the atmosphere. It functions best in a vacuum.

The rocket principle is far from new - the Chinese first made sky-rockets centuries ago. The foremost pioneer in rocket propulsion in this country was Dr. Robert H. Goddard who began his work as early as 1916. It was not until World War II that the application of his data was used, other than experimentally. The bazooka of the U. S. Army and the V-2 rocket of the Germans are early examples of applied rocketry. Since World War II, progress in rocket propulsion has been almost exponential, and the present "state of the art" is only the beginning.

Since the days of the first powered flight by the Wright brothers, progress in aviation has been so rapid with regard to speed and altitude, that human frailty was found to be the chief factor which threatened to hinder further progress. The need for study of human factors in flight was recognized, and a special school was established for this purpose. The Army School of Aviation Medicine came into being in 1921 at Mitchell Field, New York, and in 1931 was moved to Randolph Field, Texas.

Because of such rapid progress in aeronautics and in rocket propulsion, Major General Harry G. Armstrong, as Commandant of the School of Aviation Medicine at Randolph Air Force Base, Texas, in 1949, established the Department of Space Medicine.

Aviation Medical research has played an important part in the development of aviation during the past 40 years, and will continue to do so to an even greater degree, in the preparation of man for space flight.

This rapid development of aviation, which has carried us beyond the brink of space, has necessitated a revision of our concept of the stages of manned flight, especially with regard to the present and future stages. The revision is illustrated in this slide. (Figure 3)

Many of the problems involved in this classification are extensions of those already encountered in present-day operations. These include acceleration, deceleration, oxygen supply and pressurization; but, in addition there will be many new problems not heretofore considered to any great degree in manned flight. These are climatization of a sealed cabin, carbon dioxide control, new visual problems, physiological and psychological effects of weightlessness, waste disposal, and protection from meteors, solar and cosmic radiation.

What other medical problems will be encountered in the evolution of space flight? Man already has been well into the space equivalent portion of the atmosphere in both balloons and in planes. Capt. Iven C. Kincheloe of the Air Force, Flight Test Center, Edwards Air Force Base, California, flew the X-2 to a height of 126,000 feet, or 24 miles. This is double the altitude record for manned craft at the end of World War II. A recent news item stated that an unmanned three-stage rocket has now reached the physical border of the atmosphere and has attained a speed of about 15,000 m.p.h. Will a man be able to withstand the stresses of a rocket flight? Do we know all the human factors involved, or are there some as yet unknown to us? The satellite program of the I.G.Y. should provide data to fill the gaps in our knowledge. Space Medicine research must provide the engineers with human factors data before they are ready to build a man-carrying rocket.

Perhaps the medical problems involved can best be illustrated if you will embark with me on an imaginary flight in a winged rocket to - let us say - Rome. Our takeoff point is the New York Spaceport!

Everything is ready! The hatches are closed - the few remaining items on the pre-flight check list are completed. After a briefing on the flight procedures, you recline in your contour seat just as the warning signal comes on. The fury of the rocket motors is unleashed. You experience the first factor - noise and vibration. As the power is increased the noise becomes deafening. You are very thankful that you have been provided with protection devices for your ears.

As the ship starts to move you begin to feel the second factor - a giant hand seems to be holding you firmly in your seat. This is the force of acceleration which is expressed by the term "G". One "G" is the force of gravity acting upon any body within the earth's gravitational field. The hand now holds you tighter and tighter in your seat, as the acceleration increases.

You will not weigh more than 700-800 pounds during takeoff, because in this passenger ship a liquid propellant is used. The acceleration with liquid fuel is less than with a solid fuel. Liquid propellants are stored seperately from the oxidizers, and contain less energy per unit of weight than do solids, which also contain the oxidizer in combination with the fuel. Freight rockets will use solid propellants.

The flight will last about 40 minutes, so the acceleration will continue for only about 12 minutes. As the ship's velocity increases, the noise decreases. The weighty feeling continues until motor cutoff. All at once you feel normal in weight - no! you feel light - light as a feather! You feel that, without the restraint of the seat belts, you would be floating. And you would be! It is a pleasant sensation, once you recover from the change from several G's to weightlessness, or O-G. At first you feel as if you are going over the top on a roller coaster, but after your interior becomes stabilized, you don't seem to mind at all. You rather like it.

Now you begin to look about you at your companions to observe their reactions. They are looking at you. You see expressions of relief and amazement. Suddenly, everyone begins talking at the same time.

Someone says "Let's look outside." But you remember the smoked glasses which you were given before takeoof, and the instructions, too. As an added precaution the ports have been covered with shutters and these are opened when you have all put on the smoked glasses. Now you can look at the sun and you see the bright disk with its sharp edges.

The co-pilot, over the speaker, says that you may remove your dark blasses if you do n ot look at the sun. To do so without the glasses would cause permanent damage to the retina of the eye. You can see the stars and the moon, and marvel that they can be seen with the sun in the sky, too. You look back at the earth. It seems to be lighted by a huge flood light in the dark sky; you are looking down on the bright clouds and through them you can see the blue of the ocean and the eastern coast line of the United States.

As the initial reaction begins to wear off you settle back in your seat. In doing so, you notice that only the slightest effort is required for any movement of your arms or legs. You raise your arm experimentally. If it were not attached to you, it would continue to the ceiling of the cabin. It remains elevated with no effort on your part.

You begin to notice the cabin environment. The air is quite fresh - there is no difficulty in breathing, although you are now 70 miles high and the cabin is pressurized at an 18,000 foot equivalent. The oxygen in the cabin air is at 42 percent, providing you with the same amount that you would have at sea level. Carbon dioxide produced by the passengers is removed by a chemical adsorbent, as the air is circulated. It is filtered through activated charcoal filters, and maintained at a comfortable temperature and humidity.

All these factors are automatically controlled in the climatization of the sealed cabin. It is no problem to carry enough oxygen on short flights from point to point on the globe, or to the large satellite which one day will be circling the earth in its orbit one thousand miles above the surface. Only in flights of several days or weeks will the oxygen supply be a problem.

Now the ship has reached an altitude of 100 miles and a speed of about 10,000 m.p.h. The flight path has been that of a ballistic missile, since motor cutoff. We now begin to fall back to earth. You have no sensation of falling, however, because you have been weightless for some time and are still weightless. As the ship descends to about 40 miles you feel a slight force pushing you forward, as when the driver of an automobile applies the brakes. This force is deceleration caused by the slowing of the ship due to increasing air density. Speed brakes on the wings of the ship are opened to hasten deceleration. You are in the sitting position, now, with the back of your seat toward the nose of the ship. As we approach the earth, the decelerative force becomes greater, and the speed is soon less than Mach 3, or about 2,000 m.p.h. G-force, however, is not greater than 2. Still decelerating, the pilot sets his glide path for the Rome space-port, although the ship is still over southern France.

During the descent the ship has withstood aerodynamic heating caused by friction with the air molecules. The skin of the ship glowed a dull red, but the cabin was not uncomfortable because of excellent insulation and air-conditioning. Friction heating is not a problem on takeoff because the ship passes through the denser layers of the atmosphere at relatively slow speeds, and is soon in the thin, upper atmosphere, where friction becomes less with increasing altitude.

Now the ship is landing. This procedure is very much like the landing of an ordinary air liner, and you are once again on terra firma.

On short flights such as this, protection from cosmic rays and solar radiation is provided by the ship itself.

These, then, would be your experiences during such a trip. On journeys to outer space, as to the Moon or Mars, the problems in flight would be exactly the same as those encountered during this short, space-equivalent flight.

Before a rocket ship containing a man is launched, animals will be sent to higher altitudes in rockets travelling at much greater speeds. Following these animal flights, and the successful launching of unmanned satellites, small animals will be sent up in larger satellites. When animals have been kept alive in such vehicles and brought safely to earth again, we should know all the human factors involved in orbital space flight, and plans for human satellites can be completed. Once man has participated in orbital flight and returned safely to the surface, it will be possible for him to venture into more distant space and try for the Moon.

The selection of space crews will be the most complex task of this nature yet presented to Air Force psychologists and psychiatrists. The first crews will most certainly be chosen from volunteers among the pool of highly trained jet and rocket plane test pilots, who are accustomed to flying new and untried experimental craft. These men are all highly motivated individuals who are endowed with an unusual combination of caution and daring in their flying. They are men who are able to put all thoughts, other than those of the task at hand, from their minds. These attributes were not born in them, but rather were developed through the long years of their flying experience, as a result of the handling of emergencies, and other situations which require accurate, split-second decisions. They are the men who learned early in the game that the hot pilot may well be the dead pilot, and who have survived any foolhardy tendencies they may have had as neophytes. These men will have to be their own instructors, and will form the nucleus of the pool of instructors who will train future pilots. They will also have to be well-versed in the medical problems of space flight.

The selection and training of crews who will operate in the more distant future, should begin now, at the early college level. It should be determined, via questionaires and aptitude tests, which students are most interested in space flight sciences, and from this group selections for space crews can be made on the basis of physical fitness, the ability to withstand special stresses, maturity of emotional development, a preference for teamwork, exceptional learning capacity, and special aptitudes in the sciences necessary as a background for space flight. A good sense of humor would also be an excellent quality to possess. No extraordinary degree of physical strength seems indicated at the present time. Special sense aptitudes may be much more important.

Following the selection of these candidates, their academic training should be directed toward an engineering degree with emphasis on mathematics, electronics, nuclear chemistry and physics, astronomy, and related subjects. During this phase of training, the candidates should also undergo testing for their ability to withstand the expected physical stresses, and at the same time participate in a carefully supervised physical fitness program. After graduation, flying training can begin and progress to include advanced simulator training and test piloting of experimental craft, before becoming a full-fledged space pilot. This phase could include also, complete instruction in the medical problems involved.

It appears now that it will be advisable for the space cadet to assist in the design of his spaceship, so that he can "grow up" with the ship. In so doing he will have a complete knowledge of its structure, and of the function of each part. Thus, he will be better equipped to cope with emergencies that might arise. The first crews will be cross-trained in all positions aboard.

Space flight is here now. Space travel will be in the future. How far in the future? According to estimates of the best authorities, we may have manned rockets in 5-7 years; a manned satellite in 10-15 years; a lunar voyage in 15-20 years. I certainly expect to see it myself! Interplanetary travel - in 25-50 years. Who knows? I could be here yet, when that event takes place, too! Astronautics and related space flight sciences have already been incorporated in the curricula of some of our universities.

Space law will be the natural extension of international law. At the present time, this new field of law is only a very small embryo. As the Vanguard project nears completion, the question of sovereignty over the air and space will become more and more a problem which will require international agreement, or the entire satellite program could be retarded, postponed or suspended indefinitely. Such a situation would indeed be unfortunate for all nations of the Earth, because none would receive any of the rich benefits which would result from the knowledge gained through these instruments of research. To date, no nation has objected to the passage of the Vanguard satellites over its national boundaries. This fact is an indication, at least, that all nations are already in harmony with this great project. Logically, then, it can be expected that such a project would result in a strong step toward vastly improved international relations, and a lasting peace on Earth.