MEDICAL PROBLEMS OF GLOBAL SPACE FLIGHT*

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It is not my intention to talk to you today about a trip to the Moon, or to Mars; rather, I would like to stay more on a realistic basis on this topic of space flight, and discuss the first stage in this development which is now right before our doorstep. This stage of space flight of which I am speaking is the connecting link between todays long distance global flight and interplanetary space travel, and can be called "global space flight." But even this first stage of space flight reveals so many novel and fascinating things that it would be well worth while to discuss at least some of them.

The various stages of human flight are determined by the distances covered on or away from the Earth; in other words, the destination of the flight, and also by the speed of the vehicle, and finally, by the physical and physiological properties of the environment.

As a point of departure, lets start with the characteristics of todays long distance flight. In todays long distance flights or global flights - as we might call them -

*Given to Seguin Rotary Club at Luncheon, on 6 Sept 1955.

our planes carry us with subsonic speed, under normal gravitational conditions, through the lofty but still low regions of the atmosphere, in pressurized cabins, from one place on the globe to another distant place on the globe, in a matter of a single day. Replacement of the propeller engine with the jet may eventually cut this time in half. We still fly, however, with the support offered by the Earth's atmosphere, even if some of the conditions - for instance, the cabin's air pressure - are artificially normalized. Thus, flight with propeller and jet propulsion is, fundamentally, travel by air.

The rocket, independent of the presence of air, makes possible flights into the upper atmosphere and beyond, into the vacuum of space. In fact, the rocket is even more efficient in a vacuum. Thus, the rocket has opened a new frontier for the flyer - the vertical frontier.

What then is the first outpost on this frontier, or the first stage of space flight? Or, what are the medical problems involved?

The conditions found in the atmospheric regions already reached by manned rocket powered planes and unmanned rockets - from the standpoint of manned flight are, more or less, equivalent to those in free interplanetary space. In fact, the greater portion of the atmosphere is space equivalent, and to cope with the conditions found in these areas, the same protective measures are necessary as those required in free space. Briefly: above 50,000 feet or about 15 km. the atmospheric function of supplying us with oxygen - for physiological reasons - drops to zero; at 63,000 feet or 19 km, the barometric pressure becomes insufficient to keep our body fluids in the liquid state. Between 70,000 and 80,000 feet or 22 and 25 km, it is technically difficult to utilize the atmosphere to pressurize the cabin, because the air is too thin. Moreover, compressing this thin air would produce a rather high temperature in the cabin, intolerable for the occupants; and finally, the atmosphere between 60,000 to 140,000 feet is enriched by ozone; compressed to physiological pressure the air from these altitude levels would contain ozone in such high concentration as to be toxic. For all these reasons, then, the presurization of the cabin in the conventional manner is impossible above 70,000 feet. We must, therefore, change to a new type of cabin, the so-called "sealed cabin." This is a completely closed cabin in which the life sustaining air must be taken along at the start. For example, oxygen, consumed by the occupants in respiration, must be replaced; the carbon dioxide produced in the same process must be removed; temperature, humidity, and odors must be controlled. Such are the medical problems confronted in a sealed cabin -

the same type of cabin that will be built into future space ships - but would even be required at a certain altitude level well within the stratosphere. The sealed cabin craft has no life sustaining contact with the earth's atmosphere; it is a world all its own - a little earth, a "terrella." The USAF School of Aviation Medicine, Randolph Field, Texas, now has an experimental sealed chamber in which we can study the various climatic factors involved and the best means to control them.

At altitudes above 120,000 feet we enter an area where the protection against cosmic rays and solar ultra violet radiation by the atmosphere ceases, and the cabin's hull must take over this atmospheric function.

At 75 miles the cabin's hull must also take over the atmosphere's protective function against meteorites. For this purpose a meteor bumper or meteor screen, consisting of an outer layer of steel around the hull of the ship, has been suggested. The possibility of collision with meteorites, however, is rather remote.

At about the same altitude, scattering of visible light by the air molecules, which is responsible for our beautiful blue daylight, ceases. This produces the so-called darkness or twilight of space with the stars visible all the time. But the earth reflects about 50 percent of the incident sunlight in form of a blue-green silver veil. Twilight around and above, and reflected light from the Earth beneath, indeed presents a strange situation of reversed light distribution.

So much for the physiological qualities of the environment encountered in the extreme altitudes.

Another consideration, is the movement of the vehicle, through the environment encountered at extreme altitudes, with very high speed, which also reveals some novel problems of the things to come. Present day airliners fly with subsonic speed. The experimental flight of Charles Yeager in 1948, however, when he broke the sonic barrier, placed us into the supersonic speed range with the present record beyond twice the speed of sound, or, Mach 2. At still higher supersonic speed we run into another barrier: the heat barrier, caused by friction of the vehicle with the air molecules, posing a new problem in cabin climatization. Above 120 miles or 200 km, however, the air is too thin to cause any heat effects at any speed. Beyond this thermodynamic border of the atmosphere, we encounter frictionless movement, such as that of an asteroid in interplanetary space. Above 120 miles the temperature of the cabin's hull is governed solely by the sun's radiation.

In the supersonic speed range we encounter still another phenomenon, dynamical in nature and never experienced by man in ground travel or in conventional travel by air: the state of weightlessness.

In a horizontal flight - under the pull of the earth gravity - the airplane follows a curved line, parallel to the curvature of the terrestrial sphere. In the higher supersonic speed range, centrifugal forces begin to counteract the earth gravitational force in an increasingly noticeable degree, bringing on the phenomenon of decreased weight or subgravity. At 10,000 mph, for example, the weight of craft and crew is reduced to 60 percent; at about 18,000 mph the state of weightlessness or zero gravity is reached.

This same effect can be achieved at lower speed in a parabolic flight curve which is the typical path of rockets and rocket powered planes following an initial short period of acceleration. In all of these cases of zero-gravity the rocket craft behaves like a projectile until it returns to airplane status in the denser layers of the atmosphere. The density of the atmosphere is the factor that imposes the limit for the duration of the gravity-free state. At 120 miles or 200 km, however, the density of the air is too low to offer any resistance to the moving craft, thus allowing permanency of the gravity free state. This level has been termed "the aerodynamical border" of the atmosphere. Above this level the atmosphere is not recognizable - from the standpoint of manned flight. In terms of the meteorologist or the astrophysicist, however, it ends at an altitude of 600 miles.

Today's manned rocket powered craft have already advanced well into the area of partial space equivalence, passing beyond at least three important space equivalent levels. Animal carrying rockets have left nearly all of them behind. Unmanned two stage rockets have penetrated deep into the heart of total space equivalence. From a physiological and technical point of view, we are -at present - in the partial space equivalent phase of manned flight, a fact of far reaching significance with regard to travel in the immediate future.

At the beginning of this speech we defined the present long distance flights as "global flights." The coming phase of travel can be termed "global space flight." We stay on the globe but fly under space equivalent conditions - or more precisely analyzed: Rocket powered planes will take us at supersonic speed, under subgravitational conditions, in a sealed cabin through the space equivalent regions of the atmosphere, from one place on the globe to another distant place on the globe in a matter of a few hours. The medical problems involved are of immediate concern, the most important one is that of climatizing the cabin. With the combined efforts of the engineer and physiologist, this problem so vital for the safety of the passengers will, no doubt be solved.

The strangest condition that the passengers will experience in this sort of flight is the state of decreased weight, reduced dynamically, as already mentioned. In the supersonic speed range to be expected, the reduction of weight will be slight - perhaps 20 to 40 percent. I do not anticipate difficulties for the passenger from these subgravitational conditions. I rather expect a feeling of exhilaration. In the case of complete weightlessness, the story might be different. It is, however, still too soon to say whether zero-gravity will represent a serious medical problem or merely an interesting psychophysiological phenomenon. Expressed in a simple way: in global space flight - with regard to gravitation - the passengers fly partially under airplane conditions as in conventional global flights, and partially, however, under ballistic conditions like a bullet or a meteorite.

amount of time for readjustment. This is a familiar problem in work shifts in factories, mines, and hospitals, and in watches on ships. It has now become a problem in travel. Here the phase shift in the diurnal cycle is caused simply by traveling with or against the rotation of the earth, across the meridians. The effect comes from the local differences in time between the points of departure and arrival. In such vehicles as ships, trains, and automobiles, the difference amounts to slightly more than one hour per day. This slight change may be uncomfortable; but physiologically, it is insignificant. But when we fly across the Atlantic and cross 100 meridians we experience a time shift of about a quarter of a day. We are adjusted to the local time at the place where we took off. This time is, so-to-speak, our internal physiological time. As a consequence our physiological cycle fails to match the new astronomical diurnal cycle at the place where we land, leaving a gap of some 5 or 6 hours.

The physiological effect produced by the discrepancy between the geographic and physiologic day-night cycle - after global flights and global space flights - can be termed a "geographic-physiologic phase shift in the day-night cycle," or incomplete time or cycle adaptation."

During this incomplete time adaptation, the newcomer's physiological cycle, or "metabolic clock", behaves as though he were still in the area he just left and will take several days before he adapts himself physiologically to the local time of the new place. So much for the physiological side of the problem.

The geographical time shift is 4 minutes per meridian, one hour per 15 meridians; a 5 to 8 hour difference is easily achieved by our conventional planes in a single day on the usual flight routes between the 30th and 50th parallels. When our planes travel at 600 m.p.h., a time difference of 12 hours, corresponding to 180 meridians, will be possible within one day, and in global space flight, in a few hours, thus entailing a complete cycle inversion.

If we fly in the middle latitudes with the speed of daylight - 700 miles per hour - leaving Paris for New York at noon or lunchtime, after 5 hours of flight, we arrive at Noon or lunchtime, but our body says that it is evening and time for dinner.

These examples may suffice to show the complexity of the physiological time factor in global space flight. The less time-consuming, the more time-confusing. However, the main features of this complex are quite simple, and clearly visible in present day global flight.

The phenomenon of incomplete cycle adaptation imposed by travel is important in present day global flights and even moreso in future global space flights, with regard to the following points:

The time element should be considered in scheduling the sessions for meetings of diplomatic, economic, or military missions, after long distance flights. As a rule, during the first two or three days after flights that involve the crossing of five or more time zones, meetings of a decisive nature should not be scheduled in the morning at the end of eastbound travel, nor during the afternoon following westbound trips.

This time element is of special medical interest with regard to diagnosis of feverish diseases and treatment of sick people after global flights and global space flights.

It is of interest, finally, regarding the permissible frequency of change in cycle of the global pilots and global space pilots.

In travel by land or sea, the time shift remains at intracontinental and intraoceanic ranges. In modern global flights and global space flights, it reaches the level of intercontinental and global dimensions.

We have now reached the point in flight where we must consider the earth not merely as the good old "terra firma" of of the ancients, but rather as a rotating planet.

In conclusion, I would like to touch upon the extension of global flight and global space flight into interplanetary space travel. As previously mentioned, at 18,000 mph or 5 mps. the state of zero-gravity is reached. This is the so-called orbital velocity, the speed which will enable a craft to circle around the globe in a fixed circular orbit as an artificial satellite. This eventual stage may be called circumglobal space flight. The medical problems involved are similar to those in global space flight except that here we deal with the gravity free state over a longer period of time and possible cosmic radiation hazards. Also, the physiologic day-night cycle of the crew must be kept in balance during the flight. All this holds true for the next and final stage: with increasing speed, beyond 5 mps, the circular orbit will expand into an elliptic orbit and at 7 mps into a parabolic trajectory; when this speed is attained the craft will break away from the earth's gravitational control and escape into the depths of interplanetary space. This then will be interplanetary space travel.

At present we have reached, in a two-stage rocket, 30 percent of the orbital velocity and 20 percent of the escape velocity. A three-stage rocket or an atomic rocket may bring in the remaining percent.