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DEFINITIONS AND SUBDIVISIONS OF SPACE

Bioastronautical Aspect

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Whenever matters of astronautics are discussed, the word space is used in a great variety of ways, such as outer space, deep space, free space, interplanetary space, cosmic space, and so on. But space is an immensely vast area even within our solar system and its environmental conditions are by no means uniform. We need an exact definition of what is meant by these terms, where above the earth's surface space begins, and what subdivisions of space may be conceivable and practical. In brief, we now need a kind of "geography of space"— what we might call spatiography. This field refers, of course, only to the empty space itself. The description of the environmental conditions on the celestial bodies is called planetography, of which geography (Earth), areography (Mars), and selenography (Moon) are special cases. Both spatiography and planetography are subdivisions of an all-embracing cosmography. In the following we shall confine our discussion to the space of the solar system based essentially on space medical considerations or on bioastronautics. A spatiography of this kind may also be useful for other aspects of astronautics such as space technology and space law.

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The first and perhaps the most important question that interests us is: Where above the earth's surface does space begin? According to theories in astrophysics, the atmosphere as a material continuum extends to about 1,000 km., or 600 miles. In this region collisions between air molecules or atoms become very rare and the atmosphere thins out in the form of a spray zone (exosphere) into the nearly perfect vacuum of space. But this astrophysical aspect is not relevant to astronautics and especially not to manned space flight. In this respect the cessation of the atmospheric functions and effects determine the border between atmosphere and space. Without going into details —

As low as 15 km. (about 10 miles) and 20 km. (12 miles), the atmospheric pressure functions which provide the lungs with oxygen and keep the body fluids in the liquid state are no longer effective.

The low air density at 24 km. (16 miles) makes necessary the use of a sealed cabin for the crew.

At 40 km. (24 miles) we are beyond the region of absorption for cosmic rays.

The same is true at 45 km. (28 miles) concerning ultraviolet of solar radiation.

The 50-km. (30 mile) level is the limit for aerodynamic lift and navigation even for the fastest winged craft.

At about 100 km. (60 miles) the rarified air ceases to scatter light and to transmit sound, resulting in the strange darkness and silence of space.

At 120 km. (75 miles) we are beyond the meteor-absorbing region of the atmosphere.

This is practically also the aerodynamic heat limit.

And, finally, at about 200 km. (120 miles) air resistance approaches zero. This mechanical border of the atmosphere is its final functional limit. At this altitude the "appreciable" or effective atmosphere terminates.

For the whole atmospheric range within which the various atmospheric functions for manned flight cease, the term aeropause has been suggested.

We can also explain the environmental situation in this region by saying that with the vanishing of its functions the atmosphere becomes partially space equivalent at 15 to 20 km. and progresses step by step to total space equivalence at 200 km. as far as the effectiveness of the atmospheric functions is concerned.

Three of these steps on the ladder to space, or in the intra-atmospheric space-equivalent region, where atmosphere and space overlap, deserve special attention:

1. The physiological zero line of air pressure at about 20 km. (12 miles) at which the environment for the unprotected human body attains the equivalent of a vacuum;

2. The technical zero line for useful aerodynamic lift and navigation by control surfaces at 50 km. (30 miles). Above this line we deal exclusively with ballistics, and navigation by control surfaces has to be replaced by reaction control. This altitude is considered by some law experts the limit for national authority over the airspace; and –

3. The mechanical zero line of air resistance at about 200 km. (120 miles). Here we enter the region of the "Kepler Regime" where

the laws of celestial mechanics, unhindered by air resistance, are fully effective. It is here where space in its connotation "outer space" actually begins.

Such is the picture of the border between atmosphere and space based on a physiological and technological analysis.

For astronautical purposes, what are the possibilities of subdividing the void of our solar system beyond the earth's mechanically effective atmosphere?

At first glance it may seem strange to draw borderlines or demarcation lines in an environment in which emptiness is the rule and concentrations of matter, in the form of celestial bodies, are the exceptions. There are, however, several ways to subdivide space based on environmental-ecological, on gravitational and on topographical astronomical considerations.

First, of vital interest to the astronaut, are the environmental-ecological differences in the environment of <u>space itself</u>, before he considers the celestial bodies.

To begin with, the space environment in the <u>vicinity of celestial bodies</u> is different from that in free interplanetary space. It shows some peculiarities caused by the mere presence of their solid bodies, by optical properties of their surfaces, and by forces originating in these bodies and extending into space.

In the vicinity of the earth, for instance, on one side we are protected from cosmic rays and meteorites by the solid body of our globe itself — just as we are protected on one side of a house against rain, hail, or wind. Other peculiarities of the space environment near the earth are its shadow, its own radiation, and reflected solar radiation, which influence the heat balance of a space vehicle and pose special visual problems.

The forces which cause special regional environmental differences in the space near the earth are those of the geomagnetic field. The magnetic field of the earth strongly influences the influx of corsuscular rays of solar and cosmic origin by channeling them into the polar regions and storing them or deflecting them back into space over the equatorial regions. The polar lights and the two high intensity radiation belts, above 600 miles over the magnetic equator, recently discovered by James van Allen by means of the Explorer Satellites, are manifestations of this geomagnetic influence upon the density distribution of ray particles in earth near space.

For all these reasons, space in the vicinity of the earth is distinctly different from open interplanetary space. If we wish to emphasize this fact, we might use for that region in which the earth's influence upon the environmental-ecological qualities of space is distinctly recognizable the designation "circumterrestrial space." The same consideration applies more or less to the other planets and the moons (for instance circumlunar space). For the circumterrestrial space or nearby space, we might assume an extension up to 5 earth radii.

Depending on the outer boundary of the great radiation belt. Beyond this region we enter deep space.

In a certain respect, however, the earth's influence reaches much farther into space than explained above. The factor in question is gravitation, the environmental dynamical substrate for space navigation.

Theoretically, the gravitational field of the earth, as of every other larger celestial body, extends, of course, to infinity in terms of celestial mechanics; but the astronaut is especially interested in those areas in which the gravitational force of a celestrial body prevails over those of other celestial bodies. In the astronautical literature they are known as spheres of gravitational influence. We might call them, briefly, gravispheres.

The gravisphere includes the potential satellite sphere which in case of the earth reaches as far as about 1,500,000 km. or nearly 1,000,000 miles. This is the reach of the earth's satellite holding power. Beyond this distance at which interplanetary space begins, the gravitational field of the Sun becomes gradually predominant for a space vehicle, and the Earth can exert some influence upon it only in the form of disturbances. The potential satellite sphere of our Moon, according to Oskar Ritter, extends to about 60,000 km. from its center; that of Venus, 1,000,000 km., and of Mars, 500,000 km.; Jupiter's potential satellite sphere is more than 50,000,000 km. in radius.

The first-order gravisphere in our solar system is, of course, the gravitational empire of the Sun, which blends far beyond Pluto with the gravitational "no man's land" between the stars. As second-order gravispheres then can be considered those of the planets, and as third-order gravispheres, those of the moons, the smallest gravitational province in our solar system. Thus we arrive at a subdivision of space based on the extension of the gravitational territories of the various celestial bodies.

This dynamographic aspect of space may be useful for a better understanding of the nature and spatial extension of satellite flight and (gravitational) escape operations such as lunar, interplanetary, and planetary space flights.

But we can subdivide space on still a larger scale on the basis of intensity variations of solar electromagnetic radiation as we encounter them when traveling through the whole planetary system from Mercury to Pluto — in other words, as we observe them as a function of the distance from the Sun. Because this function follows the inverse square law, these variations are very extreme and they involve, of course, all important portions of the solar electromagnetic spectrum (heat rays, light, and ultraviolet rays). In fact, we would not go too far by speaking of a zonation of interplanetary space in this respect, an analogon to the torrid, temperate, and cold zones in the earth's climate.

Such line of thinking leads to the assumption of a zone which is not too hostile to space operations and in which the conditions on planets are compatible with the possibility of life as we know it. This zone may extend from Venus to Mars and can be called ecosphere of the Sun. A further discussion of this ecological subdivision of the space within our solar system, however, and also that of a topographical astronomical subdivision of space (such as cislunar, translunar space (Krafft Ehricke), interstellar, intragalactic, and intergalactic space) goes beyond the scope of this symposium.

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