Orbital Characteristics of Earth and Moon Satellites As a Basis for Space Medical Studies

HUBERTUS STRUGHOLD, M.D., Ph.D. and OSKAR L. RITTER, Ph.D.

IN A RECENT publication,[1] the gravitational situation in solar space has been discussed with regard to the spheres of significant gravitational influence, or *gravispheres*, of the planets from Mercury to Pluto and of several moons. It was pointed out that a distinction can be made between the inner part of the gravisphere and the outer gravisphere. The inner gravisphere is the region within which the gravitational influence of a celestial body is dominant, in the sense that it can hold another body captive in orbit as a satellite. This region, therefore, can also be called the *potential satellite sphere* of the body. As an example, the earth's potential satellite sphere reaches as far as one and one-half million kilometers (one million miles), or four times the distance to the moon. In the outer gravisphere, extending several million miles beyond this region, the earth still exerts a marked if decreasing influence upon the orbit of another celestial body or a space vehicle.

The recent successes in the penetration of space with unmanned vehicles puts this spatial gravitational aspect more and more into the focus of astronautical and public interest. It therefore appears useful to discuss in more detail the gravitational situation in that region which is of immediate astronautical interest: the earth-moon area. We shall here concentrate our attention especially upon the orbital velocities and periods of revolution of artificial satellites at various levels within the gravispheres of the earth and the moon. This is of space medical interest insofar as it gives information about the periods of time during which a satellite moves through the shadow of the primary celestial body or is exposed to solar irradiation. It is also of particular interest with regard to the Van Allen Radiation Belt of earth.[3]

As already mentioned, the potential satellite sphere of the earth has a radius of 1.5×10^6 kilometers (930,000 miles). So far, in a careful search by C. Tombaugh and co-workers,[2] no other natural satellites of earth (except the moon) have been found with a brightness larger than 15th magnitude, which corresponds to a size of about 1 ft. diameter at a height of 1000 miles, or 1000 ft. at the boundary of the satellite sphere. The moon, at a mean distance of 384,000 km. (239,000 miles), moves with a mean orbital velocity of 1.0 km./sec. (0.63 mi./sec.) in 27.3 days around earth. The orbital velocity near the earth's surface, if earth had no atmosphere, is 7.9 km./sec. (4.9 miles/sec.). Of course, we can not reckon with satellites of noteworthy lifetime below 200 km. (120 miles) due to atmospheric drag.

Table I shows the orbital velocities and periods of revolution at this mechanical border of the atmosphere and above at selected intervals. The first part of the table covers the space below the Van Allen Radiation Belt which may permit manned satellite flights.

The second part of Table I gives orbital data in various intervals up to 70,000 km. (43,000 miles), including the often discussed 24-hour orbit at 36,000 km. (22,300 miles). This range covers the greater part of the Van Allen Radiation Belt and permits derivation of the fraction of time during which a vehicle in a polar or otherwise inclined orbit would be exposed to their radiations.

The third part of Table I shows the orbital velocities and periods of revolution up to the border of the satellite sphere (neglecting perturbations by the moon and sun). This range

From the Advanced Studies Group, USAF Aerospace Medical Center, Brooks Air Force Base, Texas.

TABLE I. EARTH SATELLITES

Altitude above Surface km	Distance from Center km	Distance in Units of Earth's Radius —	Distance in Per Cent of Radius of Earth's Gravisphere %	Speed in Orbit km./sec.	Period of Revolution (sidereal) days hr. min.	Altitude above Surface miles
(0	6,371	1	.425	7.909	1 24	0)
(100	6,471	1.016	.431	7.848	1 26	62)
200	6,571	1.031	.438	7.788	1 28	124
300	6,671	1.047	.445	7.729	1 30	186
400	6,771	1.063	.451	7.672	1 32	249
500	6,871	1.078	.458	7.616	1 34	311
600	6,971	1.094	.465	7.561	1 37	373
700	7,071	1.110	.471	7.507	1 39	435
800	7,171	1.126	.478	7.455	1 41	497
900	7,271	1.141	.485	7.403	1 43	559
1,000	7,371	1.157	.491	7.353	1 45	621
1,500	7,871	1.235	.525	7.116	1 56	932
2,000	8,371	1.314	.558	6.900	2 07	1,243
3,000	9,371	1.471	.625	6.521	2 30	1,864
5,000	11,371	1.785	.758	5.920	3 21	3,107
10,000	16,371	2.570	1.09	4.934	5 47	6,214
20,000	26,371	4.139	1.76	3.888	11 50	12,427
35,868	42,239	6.630	2.82	3.072	1 00 00	22,287
50,000	56,371	8.848	3.76	2.659	1 13 00	31,069
70,000	76,371	11.987	5.09	2.385	2 07 54	43,496
	100,000	16.70	6.67	1.996	3 15 26	
	150,000	24.54	10.0	1.630	6 16 37	
	200,000	32.39	13.3	1.412	10 07	
	300,000	48.09	20.0	1.153	18 22	
	384,405	60.33	25.6	1.018	27.3	
	500,000	79.48	33.3	.898	40.5	
	700,000	110.9	46.7	.759	67.1	
	1,000,000	158.0	66.7	.635	114.5	
	(1,500,000	236	100	.519	210)	

included the moon's orbit. At one million km. a satellite would require 114 days to circle the earth. As already mentioned, the potential satellite sphere of earth reaches up to 1.5×10^6 km. This is the dynamical gravitational divide between the earth's gravisphere and that of the sun.

With reference to the Van Allen Belt, we may call the orbits below the Belt "low orbits"; those within the range of the Radiation Belt "medium orbits"; and those above, "high orbits." This subdivision is of space medical significance with regard to shielding.

The moon moves within the earth's gravisphere with a sphere of predominant gravitational influence of its own. It extends to 58,000 km. (36,000 miles) on the cislunar side and to 64,000 km. (40,000 miles), in the translunar direction. The moon's gravity is about 17 per cent of that of earth. Consequently, the circular velocity near the moon's surface is 1.7 km./sec. (1 mile/sec.).

TABLE II. MOON SATELLITES

Altitude above Surface km	Distance from Center km	Distance in Units of Moon's Radius —	Distance in Per Cent of Radius of Moon's Gravisphere %	Speed in Orbit km./sec.	Period of Revolution (sidereal) days hr. min.	Altitude above Surface miles
(0	1,738	1	2.85	1.679	1 48	0)
(10	1,748	1.0058	2.87	1.675	1 49	6.2)
30	1,768	1.017	2.90	1.665	1 51	31.1
100	1,838	1.058	3.01	1.633	1 58	62.1
200	1,938	1.115	3.18	1.590	2 08	124.3
500	2,238	1.288	3.7	1.480	2 38	311
1,000	2,738	1.575	4.5	1.338	3 34	621
2,000	3,738	2.151	6.1	1.145	5 42	1,243
5,000	6,738	3.877	11.0	.853	13 47	3,107
10,000	11,738	6.754	19.2	.646	1 7 42	6,214
20,000	21,738	12.5	35.6	.475	3 7 54	12,427
(59,000	61,000	35.1	100	.283	15 16	37,000)

Table II presents the orbital velocities and periods of revolution of moon satellites in selected intervals up to 20,000 km. The data beyond must be considered as theoretical because of the increasing influence of disturbances from earth. If the moon were an independent celestial body, a theoretical satellite at a distance of 87,000 km. would require the same period of revolution around the moon as the moon requires around the earth.

All the data in the tables refer to circular orbits around the earth or around the moon. In reality, most of the artificial satellites move and will move in more or less elliptic orbits. Nevertheless, the data on the periods of revolution are applicable as long as the semi-major axis of an ellipse equals the radius of a circular orbit. These data provide a more distinct picture of the gravitational situation in the earth-moon areas, useful for navigational and space medical considerations.

REFERENCES

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2. Tombaugh, C. W., Robinson, J. C., Smith, B. A. and Murrell, A. S.: The search for small natural earth satellites. New Mexico State University Report, June, 1959.
3. Van Allen, J. A.: On radiation hazards of space flight. *Physics and Medicine of the Atmosphere and Space.* New York: John Wiley & Sons, Inc., 1960.

Personal Problems Affecting Flight

The pilot of an FJ-4B lost directional control and swerved off the runway on attempted takeoff. At the time of the accident, the pilot was beset with extremely severe personal problems. His troubles were unknown to any of his fellow officers or his flight surgeon because the squadron had just reformed following deployment.

In his report the flight surgeon states that it is felt that the pilot was not psychologically suited to be flying at the time of the accident because of this stress. This could well have been the contributing factor in causing him to become fixated on getting airborne, the flight surgeon states. This accident, he notes, points out the necessity of the flight surgeon knowing his pilots intimately. . . . Later, investigators found the automatic parachute opening cable still attached *to the parachute.* If it had been hooked up properly when the pilot strapped in, it would have remained attached to the lap belt after seat separation.

The pilot recalled that he had had difficulty in attaching the ring of the automatic parachute opener *to the lap belt* release mechanism. Actually, he had strapped in without hooking the automatic parachute opener. If he had been unconscious or dazed after ejecting he would have been unable to actuate his parachute manually. If he had ejected at a low altitude he would not have had time to manually actuate the parachute. In either case he would have been killed.—From *Approach,* July, 1960.