AIAA Journal

RUSSIAN SUPPLEMENT

Igor Jurkevich, Editor

Published under National Science Foundation Grant-in-Aid. The Russian Supplement will appear monthly in 1963.

Evolution of the Orbits of Artificial Satellites of Planets as Affected by Gravitational Perturbation from External Bodies

M. L. Lidov

THE study of the evolution of artificial satellite orbits requires the investigation of a broad region of possible parameter values, and, when differential equations in celestial mechanics must be solved, calls for a large expenditure of time and effort even if high-speed electronic computers are used. Approximate analytical methods would seem to be the answer to this problem.

The writer's purpose in this paper is to obtain the simplest possible expressions useful for studying the evolution of a fairly broad range of satellite orbits. These expressions must reveal the basic qualitative regularities of the motion, and they must provide, with a certain degree of accuracy, a way of obtaining quantitative estimates of short-term and long-term changes.

The basic assumption made here is that there is a small enough ratio between the height of the apocenter of the satellite and the distance from the perturbing body to the central body. This naturally limits the class of orbits that can be handled by this method, but the range can be kept fairly wide by reducing precision to some extent.

The second assumption made is that any variation in orbital elements for one revolution of the satellite is small.

Approximate formulas are derived for the variation in orbital elements for one revolution of the satellite, for several revolutions, and for the period of revolution of the perturbing body. Special cases are also considered. The results are compared with those obtained by the numerical integration of the differential equations, and it is concluded that although the error in the approximate method is appreciable—of the order of several percent—the method is sufficiently accurate for research purposes and for the preliminary computation of a class of satellite orbits broad enough to be useful in actual practice.

Until very recently, the writers of papers on the evolution of the orbits of artificial satellites studied in detail the influence exerted by the departure of the earth's gravitational field from a central field and by atmospheric drag. Some writers also investigated subtler effects connected with the rotation of the earth's atmosphere. The variation in orbital parameters resulting from gravitational attraction by the moon and the sun was only estimated. These estimates showed that satellites near the earth were affected by other celestial bodies to a negligible extent which was practically unobservable by the measurement techniques then in use. However, beginning with the American satellite Vanguard I, radio measurements proved to be precise enough for these effects to become apparent. The reduction of the measurements made during the two years Vanguard I has been in orbit has shown[1] that the observed evolution of the orbital parameters cannot be explained without taking account of gravitational forces of the moon and the sun (and even of radiation pressure).

In the case of the Vanguard I orbit, the variation in perigee height in the course of a year was of the order of 5 km. Evolutionary changes of this magnitude are significant for the accurate prediction of the satellite's position but are not of decisive importance for determining its lifetime and apparently are not essential for the execution of the scientific and technical tasks it was launched to perform.

Translated from *Iskusstvennye Sputniki Zemli* (*Artificial Earth Satellites*) (Academy of Sciences Press, Moscow, 1961), No. 8, pp. 5–45. Translated by Jean Findlay, Green Bank, West Va. Reviewed by Yoshide Kozai, Smithsonian Astrophysical Observatory, Cambridge, Mass.