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THE MULTISCALE DYNAMICS OF CISLUNAR SPACE

Abstract

For the investigation of the Earth's magnetosphere and the interplanetary space outside of it, satellites with orbits of high eccentricity, large semi-major axis, and multi-day period are often used. Under the influence of the Moon and the Sun, a highly eccentric orbit of a deep space probe can become nearly circular or a nearly circular orbit might become eccentric, while orbital inclination may also exhibit large shifts. NASA's eccentric Orbiting Geophysical Observatory (1964-054A), colloquially referred to as EGO, with a semi-major axis of 12.7 Earth radii and an eccentricity of 0.918, is particularly interesting as it only reentered the Earth's atmosphere this past September, in contrast to earlier predictions that indicated a lifetime of only 16 years. A more modern example is ESA's International Gamma-Ray Astrophysics Laboratory (INTEGRAL) satellite (72-hour period with e ¡ 0.9), which despite the longevity of its original operational orbit (orbital lifetime greater than two centuries), will now come down in 2029 as its orbit was modified via a series of four thruster burns. Finally, for orbits where the semi-major axis is a substantial fraction of the Moon's, several orbital revolutions may be sufficient to lower the perigee height below the Earth if an unfavorable orbital configuration is chosen. Among the first and perhaps the most interesting of this class of very distant, highly eccentric satellites was the Soviet space probe, Luna 3 (1959 Theta 1), which circumnavigated the Moon (passing through its sphere of influence) and returned to the Earth on a new elliptical trajectory. Luna 3 twice suffered close approaches with the Moon, and despite having an initial perigee height outside of the GEO belt, after only 11 revolutions it plummeted to Earth. Luna 3 demonstrated how the passage of a space vehicle through the Moon's Hill sphere can be exploited to produce orbits of a very different kind. The Interstellar Boundary Explorer (IBEX) and the Transiting Exoplanet Survey Satellite (TESS), two modern Luna-3 like orbits, are distinguished by their high apogee distances and lunar mean-motion resonance (MMR) phasing. In this paper, we will review the multiscale dynamics of cislunar space and discuss its importance for cislunar space situational awareness and sustainability.