An analytical theory for a low-altitude lunar polar orbiter

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We have developed a fully analytical perturbation theory to compute proper elements for low-altitude (100 km) lunar satellites orbiting the Moon on nearly polar orbits. We used a mixed Lagrangian-Hamiltonian formalism, and separately accounted for the very short periodic perturbations (associated with the revolution of the satellite around the Moon), the medium periodic perturbations (associated with the rotation of the Moon), and the long periodic ones. Two contemporary models of the lunar gravity field were used to show that the difference in location of even the "frozen orbit" changes by a significant amount when the solution is pushed to comprise the high degree and order coefficients in the two models.

The algorithm based on the theory proved to be very efficient in computing and propagating the satellite orbits, because it explicitly computes the orbital elements for any time. The reliability of the software has been tested internally and externally, against the numerical integrations. A total of 52 different options of element transformations and outputs are implemented and available by making appropriate choices in a single and simple option file.

The accuracy of the achieved results is inferred using again the numerical integration. We have shown that the need for a second order (in terms of the perturbation size) solution arises in case the accuracy requirements are strict.