Investigating the optimal three-impulse transfer into the high orbit of the artificial lunar satellite

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The article examines the problem of optimum spacecraft ascent from the Earth into the high circular polar orbit of the artificial lunar satellite with the radius of 6000 km using the three-impulse bi-elliptic scheme of the so called "Shternfeld" transfer. We have carried out this analysis by taking into account the disturbances from the lunar field noncentrality, the Earth and the Sun gravitational fields as well as the engine thrust finiteness. The optimum trajectory is defined by varying both impulse control parameters and their application points. The analysis consists of two stages. At the first stage we consider two options of impulse orientation in the ideal impulse occurrence: at first the impulse orientation is set in the osculating plane by "pitch" γ and "attack" α angles; then the "yaw" angle ψ (angle of departure from the plane) is added. It is shown that with the increase of the maximum distance r_α the optimal points of the impulses application are shifted from the apsidal points of the orbits. At the same time the second, intermediate impulse is not directed along the current velocity vector. In the first, "flat" option of the impulse orientation we get characteristics which are similar to the ideal impulse apsidal case. In the second, "spatial" variant the spacecraft remaining mass slightly increases. At the second stage we take into account the engine thrust finiteness. The results obtained are very close to the impulse case.

Keywords: *spacecraft, trajectory optimization, artificial lunar satellite, three-impulse bi-elliptic scheme, "Sternfeld" transfer, Powell's quasi-Newton method*

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