

Numerical study of the time required for the gravitational capture in the bicircular four-body problem

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A gravitational capture occurs when a spacecraft (or any particle with negligible mass) change from a hyperbolic orbit with a small positive energy around a celestial body into an elliptic orbit with a small negative energy without the use of any propulsive system. The force responsible for this modification in the orbit of the spacecraft is the gravitational force of the third and the fourth bodies involved in the dynamics. In this way, those forces are used as a zero cost control, equivalent to a continuous thrust applied in the spacecraft. One of the most important applications of this property is the construction of trajectories to the Moon. The concept of gravitational capture is used together with the basic ideas of the gravity-assisted maneuver and the bi-elliptic transfer orbit to generate a trajectory that requires a fuel consumption smaller than the one required by the Hohmann transfer. This maneuver consists of the following steps: i) the spacecraft is launched from an initial circular orbit with radius r_0 to an elliptic orbit that crosses the Moon's path; ii) a Swing-By with the Moon is used to increase the apoapsis of the elliptic orbit. This step completes the first part of the bi-elliptic transfer, with some savings in ΔV due to the energy gained from the Swing-By; iii) With the spacecraft at the apoapsis, a second very small impulse is applied to rise the periapsis to the Earth-Moon distance. The solar effects can reduce even more the magnitude of this impulse; iv) The transfer is completed with the gravitational capture of the spacecraft by the Moon. The objective of the present paper is to study the time required for the ballistic gravitational capture in a dynamical model that has the presence of four bodies. In particular, the Earth-Moon-Sun-Spacecraft system is considered.