

# **NEAR EARTH ASTEROIDS TRANSFER ONTO EARTH RESONANCE ORBITS WITH THE USE OF GRAVITY ASSIST MANEUVERS**

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## **ABSTRACT**

Discovery of Apophis asteroid which initially considered as potential hazardous sky object with some meaningful probability to hit Earth in year 2036 has increased the interest for exploration of asteroids and comets. As one of consequences of this interest the studies have been fulfilled in framework of so called “Keck Project”. The Project has the aim to deliver some small enough asteroid onto Earth satellite orbit similar to the Lunar orbit. After that the manned missions are supposed to be started to this asteroid in order to explore it and to deliver its soil samples to the Earth.

In the paper the alternative approach is proposed and analyzed. The principal idea of getting the asteroid onto more convenient for explorations trajectory is to capture it on the orbit which is in resonance with the orbit of the Earth. As a tool to reach it the gravity assist maneuver near Earth is considered. It is supposed that spacecraft is to be sent to of the chosen asteroid. After landing it is to be mounted on the surface of the asteroid in such a way which would allow using the propellant in its tanks for further maneuvering together with asteroid considered as payload. The first maneuver is intended to put asteroid onto trajectory of the Earth flyby in order to fulfill gravity assist maneuver resulting in reaching the orbit with respect to Sun having resonance period with the Earth orbital motion. It was accepted that the most interesting is period equal Earth orbital period. From the catalogue of JPL near Earth asteroids, the ones were chosen satisfying supposed constraints on the velocity impulse which is necessary to transfer them on gravity assist maneuver resulting in reaching one year period. For technically feasible maneuver it is necessary to take into account the size (mass) of the asteroids – candidates for transfer onto resonance orbit. These constraints were not considered as absolute ones following the assumption that if asteroid is too big in order to apply to it velocity impulse then some part of it may be separated for transfer onto resonance orbit.

The optimal trajectories to reach asteroids surface was chosen. Criteria of optimization were accepted for different assumptions: for chemical engine units, for solar electric propulsion and for their combination. It was done as for spacecraft transfer to asteroid and landing as also for further asteroid maneuvering.

After putting the asteroid onto resonance orbit the another problem arises: have to control the further motion of the asteroid in order to keep it on this orbit or to change this orbit to do it more convenient for further exploration of the asteroid. It was shown the possibility to change the initial resonance orbit by further successive gravity assist maneuvers without losing the resonance. For example it is possible to put asteroid onto orbit which is practically similar to the Earth orbit but having some inclination to the ecliptic. For resonance orbit some station keeping maneuvers are necessary. The estimations of their characteristics are given in the paper.

Studies are fulfilled in order to understand the possibilities to fulfill manned expeditions to the captured asteroid and how to adjust the orbits of them for such missions. In framework of this analysis the estimations were received which demonstrate achievable minimum duration of such missions taking in account the contingency cases, depending on available propellant mass onboard spacecraft.

More sophisticated task connected with transfer on Earth satellite orbit of the asteroid captured on resonance orbit, with the use of several Moon flybys is explored. The conditions for solving such problem are described in terms of required propellant mass and duration of needed operations.