# Orbital Stability Regions for Hypothetical Natural Satellites

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In recent years, there has been an increase of scientific interest in asteroids culminating from a variety of rendezvous and sample return missions to characterize these bodies. In 2001, NASA's NEAR mission explored Eros from both orbit and its surface after a successful landing. The Japanese spacecraft Hayabusa visited the asteroid Itokawa as part of a sample return mission in 2005. The Dawn spacecraft has just completed its visit to Vesta and arrived at Ceres earlier this year. Finally, the OSIRIS-REx spacecraft launched in September to near-Earth asteroid (NEA), Bennu. The study of asteroids can provide clues into how the solar system formed and evolved, giving insight into the origins of organic compounds in our Solar System. Additionally, NEAs are among the deep space destinations that are a potential target for future human exploration and resource retrieval, as well as being potential impact threats to our planet.

When planning a mission to an asteroid, often the knowledge of the asteroid target is limited. This includes understanding the possibility of natural satellites that may be in orbit around the asteroid. For example, the OSIRIS-REx mission used radar imaging to conclude that there are no satellites larger than 15 m in orbit around Bennu [1]. However, there is still a possibility of satellites smaller than 15 m in diameter to be in orbit when OSIRIS-REx arrives at Bennu. If OSIRIS-REx finds a natural satellite in orbit upon arrival at Bennu, it will have significant implications for the mission design. Therefore, it is worth taking the time to understand what sort of natural satellites can exist around an asteroid. We need to understand what orbits these satellites would remain stable in for long periods of time and what are the size of these objects.

In previous work, we performed a numerical study of possible stable orbits for natural satellites around Bennu. This study included perturbations on the natural satellite from 3$^{rd}$ body gravity from the Sun, $J_2$ and higher spherical harmonics from Bennu, and solar radiation pressure. We simulated 62,000 orbits with varying initial conditions and natural satellite diameters. We determined three different orbital phenomena that are responsible for certain stable or unstable regions for natural satellites. These orbital phenomena were Sun-Synchronous orbits about the terminator plane, the modified Laplace plane, and Kozai resonance. For Bennu, the Sun-Synchronous orbits about the terminator plan provided the most interest because these orbits cause objects from less than a centimeter to a meter in diameter to be stable in similar orbits as the OSIRIS-REx spacecraft during its science phase [2].

This research is very useful for OSIRIS-REx but the breadth of information found from this numerical analysis can be non-dimensionalized and scaled to study natural satellite stability at other asteroids for future missions. These equations will provide insight into the type of orbits and size of natural satellites that are stable at a given asteroid. The analytical equations will be compared to numerical simulations around other asteroids such as $KW_4$. This will demonstrate the reliability and limitations of these equations. For example, if the equations become inaccurate for highly ellipsoidal asteroids such as Itokowa. These equations can then be used to determine where natural satellites will exist around a target asteroid and the range of diameters capable of being stable there. This will provide future missions the capability of quickly understanding where they need to search for natural satellites as the spacecraft approaches the asteroid and then make proper changes to mitigate impacts to the mission.

**References**

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