Orbital Stability Regions for Hypothetical Natural Satellites of 101955 Bennu (1999 RQ_{36})

The Origins, Spectral Interpretation, Resource Investigation, Security-Regolith Explorer (OSIRIS- REx) mission to return a sample from potentially hazardous near-Earth asteroid Bennu will become NASA's third New Frontiers Class mission when it launches in September of 2016. The mission planning team is currently investigating whether Bennu might possess any natural satellites in long-term stable orbits that could interfere with spacecraft operations in Bennu's vicinity. Bennu has been the target of an extensive ground-based observation campaign since its discovery in 1999, and those observations have ruled out the presence of any natural satellites larger than 15 m in diameter. For example, if a 1-meter diameter object is in orbit near the planned trajectory of OSIRIS-REx, a collision between the two could cause damage to the spacecraft or end the mission.

To investigate whether stable orbits exist for <15 m natural satellites of Bennu, we vary initial conditions for semi-major axes, inclinations and longitude of the ascending nodes to find a range of possible orbits that are stable. Eccentricity will not be varied as an initial condition, but with perturbations from the Sun the eccentricity may increase significantly. Semi-major axes from 1 km out to the Hill sphere will be analyzed, since highly eccentric orbits may exist that bring the natural satellites very close to the surveying orbits of OSIRIS-REx. These initial conditions will be repeatedly evaluated for multiple sized satellites up to 15 meters in diameter. Each initial condition is simulated for 1000 years or until the natural satellite escapes or collides with Bennu. If there is escape or collision, these initial conditions are considered unstable.

There are some possible stable orbits that we expect to exist for varying diameter satellites. The first possible stable region will be due to the modified Laplace plane. The classical Laplace plane is normal to the axis about which the pole of a satellite's orbit precesses. The modified Laplace plane includes Solar Radiation Pressure (SRP) perturbations, J_2 non-spherical gravity perturbations, and solar gravity. We have found that objects between 0.75 m and 15 m in diameter are stable in the modified Laplace plane for all semi-major axes.

The Kozai resonance is caused by third body perturbations on a satellite. This resonance causes libration of the satellite's argument of periapsis. This libration causes an exchange between eccentricity and inclination in such a way that the satellite's angular momentum in the Sun-Bennu orbit plane is conserved. The Kozai resonance is responsible for the stability of larger objects around Bennu. However the Kozai resonance can also cause instability if the eccentricity increases enough to cause a collision or escape from Bennu.

Finally, an orbit can be stable for a natural satellite if on a Sun-synchronous orbit. These orbits tend to stay frozen in the Keplerian orbital elements accept the longitude of the ascending node, which will precess at a rate equivalent with Bennu's orbit around the Sun. The sun-synchronous orbit is stable for objects from one cm to less than a meter in size for semi-major axes from 2-13 km.

By constructing and executing an array of detailed simulations modeling the evolution of Bennu natural satellite orbits over thousand-year time scales, we assess the possible sizes, orbital locations, and longevities of Bennu natural satellites. From these data we will draw conclusions about the likelihood of Bennu possessing natural satellites either in the past or during the current epoch, whether such natural satellites might interfere with OSIRIS- REx spacecraft operations around Bennu, and whether there are specific regions in the vicinity of Bennu within which the OSIRIS-REx team may wish to focus their efforts to search for <15 m natural satellites during the spacecraft's gradual approach to Bennu.