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Numerical analysis of polar orbits for future Enceladus missions

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Saturn's moon Enceladus gained limelight with the discovery by the Cassini spacecraft of plumes of ejected gas and ice particles from pronounced linear structures in its South Pole region called “Tiger Stripes". The small (500 km) satellite is believed to have a porous rocky core and an ice shell, separated by a global subsurface saltwater ocean. The tidal heating potentially aids in driving chemical reactions in the moon’s interior which makes it a very promising candidate where the right conditions for life formation may exist. This makes Enceladus a prime target for a future spacecraft remote sensing mission. Due to the strong gravitational perturbations caused by Saturn, the higher gravitational moments of Enceladus and additional perturbations by the other moons of Saturn, the dynamic environment for artificial satellites around Enceladus is extremely complex. As a consequence, the search for natural stable orbits is far from trivial. We carried out comprehensive numerical integrations of spacecraft orbits, with the aim to find suitable candidate orbits for a remote sensing mission. A polar orbit is desirable to further investigate the tiger stripes region, and for mapping of the global subsurface ocean. Also, the orbit should provide repeated coverage for various instruments on board the satellite. All the relevant perturbations caused by the Sun, Jupiter, Saturn and its other moons, the higher degrees and order of Enceladus’ gravity field and solar radiation pressure are taken into account. We searched for suitable orbits in inertial space by varying orbital parameters such as semi-major axis (350 to 450 km), inclination (40° to 120°) and longitude of ascending node. Moderately inclined orbits (inclination between 45° and 60°) covering the equatorial and mid-latitude regions of Enceladus were found to be stable from several months up to years. In contrast, the more useful polar mapping orbits were found to be extremely unstable due to the so-called “Kozai mechanism”, due to which a spacecraft would impact the moon’s surface within a few days. However, an example of a highly inclined orbit was found with inclination of approximately 79°, which had an orbital life time of 13 days. A longer mission in this orbit would require correction maneuvers every approximately 10 days. This would provide coverage of the tiger stripes region and allow for a global characterization of the ocean. We also determined the delta-v that would be necessary to maintain such an orbit over a mission of several months. Also, special attention was paid to satellite formation flying in this orbit to maintain a stable baseline for a distributed radar sounder system (across-track formation of multiple satellites).