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NON-KEPLERIAN ORBITS USING LOW THRUST, HIGH ISP PROPULSION SYSTEMS

Abstract

The technology of high ISP (electric and solar) propulsion systems with long lifetime and low thrust is improving and opens up numerous possibilities for future missions. Such a use of continuous thrust can be applied in all directions including perpendicular to the flight direction to force the spacecraft out of a natural orbit, defined as an A orbit, into a displaced orbit, defined as a non-Keplarian or B orbit. Such B orbits could have a diverse range of potential applications for Earth observation, space physics, human exploration and planetary science.

The identification of large families of B orbits is achieved by seeking artificial equilibrium solutions to the circular restricted three-body problem (CRTBP) in a rotating frame of reference with an additional thrust-induced acceleration. This provides an accurate model of a spacecraft in the vicinity of any planet, where each planet is defined by its unique three-body mass ratio. Planetary moons are also considered where the planet moon three-body system is considered. It follows that viewing these artificial equilibrium points from an inertial frame-of-reference, displaced, circular orbits are obtained (B orbits).

Using the equations of motion of the CRTBP we generate a catalogue of these so called B orbits corresponding to displaced orbits about the Sun, Mercury, Venus, Earth, the Moon, Mars and its moons Phobos and Deimos as well as the dwarf planet Ceres. For each system and a given thrust, a surface is produced in the rotating frame that illustrates the possible domain of B orbits for low thrust values between 0 and 300 mN. In addition to this, the required thrust vector orientation for a B orbit is obtained and illustrated. Such a catalogue of B orbits enables a quick and efficient method to identify regions of possible displaced orbits for the potential use in future missions. The sub-category of solar sail enabled missions is also considered. Finally, we consider the insertion trajectory to a range of mission examples using continuous low thrust propulsion to establish the mission-timeline and top-level budgets, including propulsion failure scenarios.