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An Analytical Theory for the Perturbative Effect of Solar Radiation Pressure on Natural and Artificial Satellites

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Solar radiation pressure is the largest non-gravitational perturbation for most satellites in the solar system, and can therefore have a significant influence on their orbital dynamics. This work presents a new method for representing the solar radiation pressure force acting on a satellite, and applies this theory to natural and artificial satellites. The solar radiation pressure acceleration is modeled as a Fourier series which depends on the Sun's location in a body-fixed frame; a new set of Fourier coefficients are derived for every latitude of the Sun in this frame, and the series is expanded in terms of the longitude of the Sun. The secular effects due to the solar radiation pressure perturbations are given analytically through the application of averaging theory when the satellite is in a synchronous orbit. This theory is then applied to binary asteroid systems to explain the Binary YORP effect. Long term predictions of the evolution of the near-Earth asteroid 1999 KW4 are discussed under the influence of solar radiation pressure, J_2, and 3$^{\text{rd}}$ body gravitational effects from the Sun. Secular effects are shown to remain when the secondary asteroid becomes non-synchronous due to a librational motion. The theory is also applied to Earth orbiting spacecraft, and is shown to be a valuable tool for improved orbit determination. The Fourier series solar radiation pressure model derived here is shown to give comparable results for orbit determination of the GPS IIR-M satellites as JPL's solar radiation pressure model. The theory is also extended to incorporate the effects of the Earth's shadow analytically. This theory is briefly applied to the evolution of orbital debris to explain the assumptions that are necessary in order to use the cannonball model for debris orbit evolution, as is common in the literature. Finally, the averaging theory methodology is applied to a class of Earth orbiting solar sail spacecraft to show the orbital effects when the sails are made to cone at orbit rates in the local horizontal frame.