ADVANCED THERMAL AND SOLAR RADIATION PRESSURE MODELLING FOR HIGH-AREA-TO-MASS RATIO (HAMR) OBJECTS: YORP UND YARKOWSKI

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1. Extended abstract

In 2004, T. Schildknecht [1, 2] discovered a new class of objects with surprisingly high area-to-mass ratios. This class of objects is highly perturbed by non-gravitational accelerations, especially solar radiation pressure for those objects, which are in near geostationary orbits. Direct solar radiation pressure is one force acting on the object via reflection and absorption forces that alter both, the attitude of the object and have effects on the orbit. Significant effort has been spent in the prediction of high area-to-mass ratio objects, which are solar radiation pressure perturbed and to model correctly the coupled orbit-attitude motion of non-spherical objects [3, 4, 5, 6, 7].

The effects of direct radiation pressure has not only be investigated in the space debris physics, but is mainly known for the orbit and attitude modeling of asteroids. In 1851 Öpik [8] recalled a pamphlet from Yarkovski, in which the effect of anisotropic thermal re-radiation was discussed, being an additional force acting on a celestial body and depending on the area-to-mass ratio of the asteroid may significantly alter its orbital evolution. Starting in 1954, O'Keefe, Radzievskii and Paddack realized that the effect is not only significant on the orbital evolution but also on the attitude of the object, which can result in significant rotation of a body. This gave rise to the name YORP effect [9].

To a very limited extend YORP effects have been studied for space debris objects [10]. In that work, emphasis has been laid on the long term effects and if YORP could be an explanation of rotation rates of large bodies such as upper stages and complete decommissioned satellites. However a highly simplified model for solar radiation pressure and thermal re-radiation has been used. The steady state model that has been utilized almost exclusively satellite radiation pressure modeling has several shortcomings. It cannot account for transient events, such as Earth shadow passages or attitude motion of the object in which it is exposing different surfaces to the sun over time. In case of actively stabilized satellites, the latter effect does not play a major role. The situation is different for space debris objects, which are in a freely tumbling attitude motion. This by natural perturbations induced attitude motion can be very rapid, leading to the fact that steady state or equilibrium conditions are never met (because the motion can be shown to be not even uniform, which would allow for an average equilibrium conditioning).

In this paper developed a higher fidelity model for the modeling of accelerations caused by solar radiation pressure and thermal re-radiation and shows the effect on high area-to-mass ratio objects (HAMR) object's orbit and attitude dynamics is shown. The transient modeling takes shadowing

effects such as Earth shadow passes and self-shadowing into account. It turns out that the perturbations are massive even within shortest time periods, leading to a rapid attitude motion and realization of both, YORP and Yarkowski effect. The results of the higher fidelity model are compared to the standard steady state approximation, which turns out to be far off. In a last step the new development of a computationally faster average model is shown, which causes only small errors compared to the high fidelity model and is hence a better choice compared to the standard steady state approximation for HAMR space debris objects.

2. References

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