ASTEROID'S ORBIT AND ROTATIONAL CONTROL USING LASER ABLATION: TOWARDS HIGH FIDELITY MODELLING OF A DEFLECTION MISSION

Massimo Vetrisano[1], Nicolas Thiry[2], Chiara Tardioli[2], Juan L. Cano[1] and Massimiliano Vasile[2]
[1]*Deimos Space S.LU,* Ronda de Poniente, 19, 28760 Tres Cantos, Madrid, Spain*, +34 918063450*,
{massimo.vetrisano, juan-luis.cano}@deimos-space.com
[2] *Department of Mechanical & Aerospace Engineering,University of Strathclyde,*
James Weir Building, 75 Montrose Street, University of Strathclyde, Glasgow **|** *G1 1XJ* **|** *t:0141 548 2326,*
{nicolas.thiry, chiara.tardioli, massimiliano.vasile}@strath.ac.uk

Keywords: *asteroid threat mitigation, asteroid ejecta, laser ablation, asteroid deflection, rotational control.*

Abstract

This article presents an advanced analysis of a deflection mission considering the coupled orbit and attitude dynamics of an asteroid deviation mission through laser ablation. A laser beam is focused on the surface of an asteroid to induce sublimation. The resulting thrust produced by the jet of gas and debris from the asteroid, directed as the local normal to the surface, is employed to contactless manipulate its orbit. This paper focuses on the laser-based deflection and rotational control of a small Earth-crossing asteroid, considering 3 up to 20 years operations. Based on the theoretical model of a laser-based deflector, an optimal hovering distance for the spacecraft operations and required power are first computed. The computation includes, among others, the effect of contamination which has an impact on the available power at the laser and consequently on the achievable thrust. A stability analysis of the orbit evolution for big size ejecta will be also considered in order to identify relatively safe and debris free trajectories for a spacecraft carrying the laser.

The effect of an off-set of the induced thrust vector with respect to the centre of mass will also be analysed because it can cause a variation of the angular velocity. In fact, this produces a variation of the sublimation as shown in Figure 1 (left) which affects both the orbital and attitude motion. Preliminary results show that it is not possible to significantly decrease the initial 175 revolution per day of 100 m asteroid using relatively low power lasers (below 1 MW) during short period operations as reported in Figure 1 (right). Nonetheless, the control of the coupled orbit and rotational motion of the asteroid represents one of the key aspects contributing to the success of this deflection technique over long operational periods.
Previous studies ([1], [2]) considered a technological demonstrator for a 4 m diameter asteroid, where simplified models in both physical characterisations of the ablation process and of the asteroid's ellipsoidal regular shape were used. In this paper the asteroid is modelled as a tumbling object with an arbitrary polyhedral shape, using actual asteroid data from radar observations scaled down to the considered mean dimension. The deflection of the asteroid over the pushing time with respect to its nominal orbit is then simulated through a semi-analytical approach ([3]).

The results will be compared to the ones obtained using an equivalent regular ellipsoid and nominal operating conditions with no angular control. As seen from Figure 2 (left), if the thrust was purely tangential in the orbital frame the overall deflection for 100 m asteroid could be up to 160,000 km over 20 years. Preliminary results indicates that the fact that the laser needs to adjust

continuously its pointing affects the net deflection, reducing the overall effectiveness of the ablation process. In fact Figure 2 (right) shows that the final deflection will be about 60,000 km with a reduction of more than 60%. The current analyses suggest that satisfactory level of deflection would require higher powers at the laser or spacecraft replacement after certain time in order to reduce the contamination effects on the solar arrays caused by ejecta.

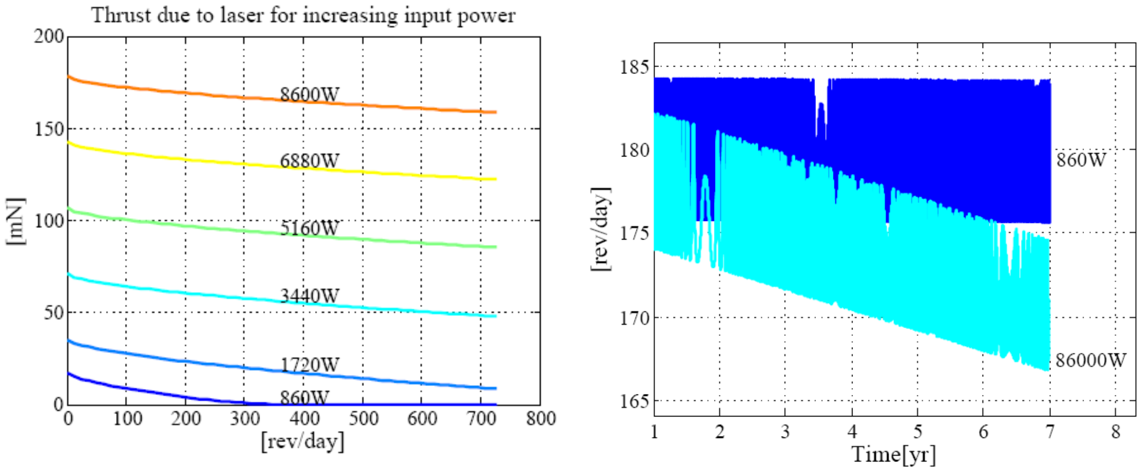

Figure 1. Thrust as a function of asteroid angular velocity for increasing laser powers (left), and controlled rotation with different available powers.

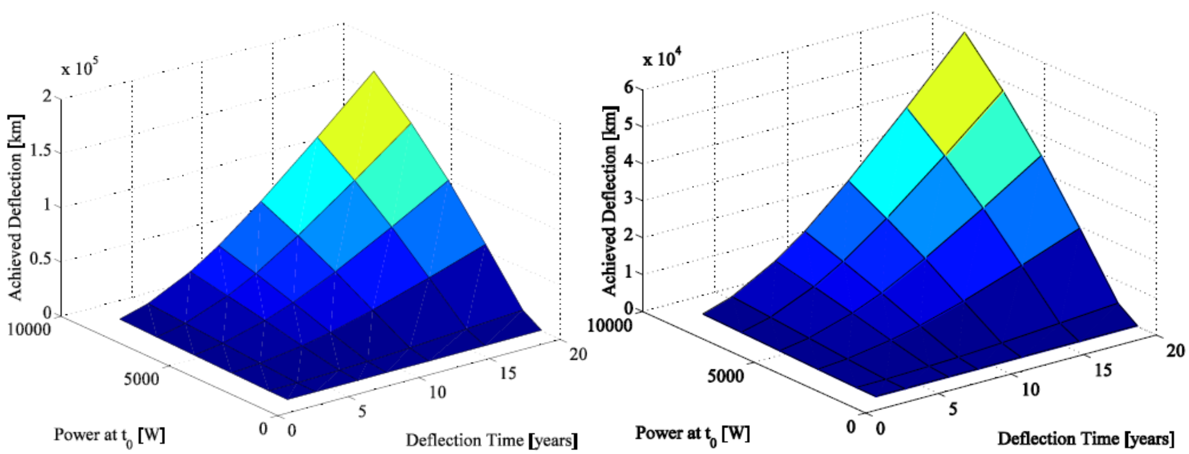

Figure 2. Deflection for varying available powers and deflection times: considering pure tangential thrust (left) and thrust generated according to the morphology of the rotating asteroid.

References

[1] Vasile, M,, Gibbings, A., Vetrisano, M et al.: Light-Touch2: A Laser-Based Solution for the Deflection, Manipulation and Exploitation of Small Asteroids. Planetary Defense Conference 2013, Flagstaff, USA.

[2] Vetrisano, M., Colombo, C. , Vasile, M., 2014: Asteroid Rotation and Orbit Control via Laser Ablation. Paper submitted to the Journal of Advances in Space Research.

[3] Vasile, M. & Colombo, C. (2008) Optimal impact for asteroid deflection. Journal of guidance, control, and dynamics, 31(4), 858-872.