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EXPERIMENTAL CHARACTERIZATION OF THE THRUST INDUCED BY THE LASER ABLATION ON AN ASTEROID

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ABSTRACT

Past analysis gained from a series of comprehensive experiments has demonstrated the effectiveness and sensitivity of laser ablation as a potential method for the contactless deflection of Near Earth Asteroids [Gibbings et al, 2012a; Gibbings, 2012]. For a given optical surface it was shown that the contamination caused by the ablated ejecta was significantly lower than otherwise predicted in the current model. In particular, the density and absorptivity of the deposited material was much lower, while the accumulative thickness was comparable. The deposited material was also loosely bound to the underlying substrate. It could therefore be easily removed by applying a small vibration and/or an increase in the local surface temperature [Gibbings et al, 2012a]. These results lead to an improvement in the contamination model. This is considered to be one of the key drivers in evaluating the performance of laser ablation. From these initial investigations, a set of more detailed and inclusive laser ablation experiments have been performed. This aimed to improve the modelling of the mass flow rate of the ablated ejecta and the associated thrust

model. At present a number of interesting discrepancies exist between the experimentally measured, theoretically assumed and predicted features.

The mathematical model describing laser ablation is currently based on three fundamental assumptions. This includes: 1) the formation of the ejecta plume is similar to a rocket exhaust in standard methods of rocket propulsion; 2) the asteroid is a spherical, dense and homogenous body and 3) the ablated particles of ejecta will immediately re-condense and stick to any exposed surface. These assumptions require further experimental validation and must therefore be either accepted, eliminated or updated. This analysis has been achieved by using a 90 watt, continuous wave, fibre-coupled semiconductor laser. Under vacuum conditions a series of detailed laser ablation experiments have been performed. Each experiment was repeated for a number of different asteroid analogue target materials. This aimed to represent the diversity within the Near Earth Asteroid population. It is inclusive of re-accumulated rubble piles, monolithic structures and porous bodies. Assessed parameters included the direct measurement of the mass flow rate, the temperature of the ejecta plume and the orientation of the thrust direction. This has enabled specific advancements within the ablation model to be considered. This included the energy absorption within the target material, the formation of the Knudsen layer and the incongruent ablation of the target material. It is also of paramount importance to understand the three dimensional energy balance of sublimation and the effects of a de-focused laser beam.

This paper reports on the new results and analysis gained from the laser ablation experiments. It will present, in detail, the recently advanced ablation model and its overall effect on the mission analysis and design of any laser ablation based deflection mission. Furthermore, the paper will show whether the momentum coupling achieved through laser ablation is better than that of an ion-engine based system.

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