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Optimizing Surface Ablation Deflection in the Presence of Realistic Asteroid Topography and Rotation

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ABSTRACT

Surface ablation can be used for hazardous asteroid deflection (Melosh et al, 1994) through heating of the surface by using mirrors to reflect sunlight or directly with lasers. In either case, the impulse from ablated material acts in the asteroid surface normal direction. In order to optimize the deflection to maximize the minimum orbit intercept distance (MOID), the ΔV should generally be aligned with the asteroid's orbital velocity direction (Kahle et al, 2006; Carusi et al, 2002), which efficiently changes the semi-major axis. Thus to maximize the deflection, material should be ablated from portions of the surface when the normal is aligned with the orbital velocity direction. If the asteroid were a sphere, this would be simple because the ablating spacecraft would simply target the leading (or trailing) of the asteroid. However, for realistic asteroids the variation in topography means that this technique will be inefficient as the surface normal is generally not aligned as desired. Furthermore, since asteroids are rotating bodies, the orientation of the topography with respect to the orbital velocity is constantly changing.

This paper has two purposes. First, we will quantify the actual decrease in efficiency of an ablation deflection strategy if the topography is not taken into account. This will be done for three representative small asteroids for which shape models are available - Golevka, Itokawa, and Bennu - which are shown in Fig. 1. Efficiencies for strategies targeting only a single point on the asteroid, or for those which illuminate a swath of the asteroid surface (Schweickart et al., 2004) will be presented.

Figure 1 - Shape models of asteroids Golevka (left), Itokawa (center), and Bennu (right) used in this study.

The second purpose of this paper is to develop a control strategy to mitigate these effects if the shape is known. Initially this consists of optimizing the set of points on the asteroid surface to target that are most closely aligned with the desired impulse direction over the spin of the asteroid. This set of desired ablation targets will then be fed into a simulation which models the spacecraft and asteroid dynamics to determine constraints on the spacecraft system. Various spacecraft-asteroid relative orbit configurations will be investigated, starting with the ideal case of the spacecraft at a fixed point relative to the asteroid center-of-mass, and culminating with a full integration of the spacecraft orbit to assess the possible orbits and their associated fuel requirements for achieving a desired deflection.

Recommendations on system requirements to achieve successful ablation deflection in light of these realistic asteroid shapes will be included.

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