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Keyhole Maps for Post Deflection Impact Risk Assessment

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Results from hyper-velocity collision studies suggest that crater ejecta contribute significantly to the total momentum transferred to an asteroid during a kinetic impact [1, 2, 3, 4]. This can work in favor of potential deflection attempts. Knowledge on the ejecta-generated momentum can be used, for instance, to optimize the effective mass of an impactor required to change a target's velocity vector by a certain amount. Even relatively large uncertainties in the total mass, as well as the speed and direction of the ejected material, do not necessarily prevent a successful deflection operation, if those uncertainties are quantifiable and accounted for in the deflection mission planning [5]. Large uncertainties in the delivered momentum, on the other hand, weaken predictions of the post-impact orbit. Without accurate information on where an asteroid is 'parked' after a deflection attempt, it is difficult to guarantee that the same object does not become a concern for planetary safety once again in the future. In the worst case, the target asteroid enters a secondary gravitational keyhole rendering the deflection attempt moot by retaining a high probability to collide with our planet at a later date. In order to avoid such scenarios, we demonstrate how to best target an asteroid during a kinetic deflection maneuver so as to exclude Earth impacts in the forseeable future. To this end we combine high-precision orbit propagation with a deflection model that takes the shape of the target asteroid and its influence on the ejecta momentum vector into account [e.g. 6]. This allows us to map out 'no-strike zones', areas on the asteroid's surface that, when hit, could potentially lead to a secondary keyhole passage and cause the asteroid to collide with the Earth at a later epoch. Similarly, impact areas that steer the asteroid safely away from keyholes are highlighted. The proposed methodology allows for a more efficient and safe application of kinetic impact based deflection techniques. Having a cumulative impact probability of 3.7×10^{-4} between the years 2175 and 2199 [7], the OSIRIS-REx mission target asteroid (101955) Bennu is well suited to illustrate the application of keyhole maps. Assuming a hypothetical deflection mission, we show how to steer Bennu clear of several kilometer-sized keyholes that are accessible during its close encounter with the Earth in 2135.

Comments:
(Oral presentation preferred)

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