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Characteristics of a High-Power Ion Beam Deflection System Necessary to Deflect the Hypothetical Asteroid 2017 PD

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ABSTRACT

Solar electric propulsion (SEP) is now commonly used in the commercial communication satellite industry and has been used successfully on a handful of deep-space science missions, most notably NASA's Dawn mission. The unique performance capabilities of SEP make it attractive for these applications. For example, the ion propulsion system on the Dawn spacecraft provided a total change in velocity, ΔV, of 11 km/s. This is roughly four times the highest ΔV provided by any onboard chemical propulsion system used in deep space. This paper presents the characteristics of an ion beam deflection (IBD) system concept based on high-power SEP to deflect the hypothetical asteroid 2017 PD. Ion beam deflection for planetary defense uses momentum transferred from an ion beam impinging on the threat object to change its orbit [1,2,3]. A potential impact in July 2027 leaves only ten years to develop and launch the spacecraft, rendezvous with the asteroid, and perform the deflection maneuver. We determine the system power level and the exhaust velocity of the electric thrusters necessary to transport the conceptual IBD vehicle to the asteroid and perform the deflection activity within the available time including the time required to develop and launch the spacecraft. In this analysis we take into account the lack of knowledge regarding key

characteristics of Asteroid 2017 PD including the diameter which may range from 100 m to 250 m, the density uncertainty, and the unknown spin state. To first order, IBD is independent of all physical characteristics of the threat object except for its mass. The same electric propulsion system would be used for transportation to the asteroid and for the ion beam deflection operation. In order to deflect the asteroid within the available time system power levels on the order of hundreds of kilowatts are likely to be necessary.

The flight system is assumed to be solar powered with the electric thrusters based on NEXIS-like gridded ion thrusters [3]. Flat, carbon-carbon grids are used to minimize the ion beam divergence angle enabling large spacecraft-to-asteroid standoff distances. The standoff distance between the asteroid and the spacecraft is determined by a tradeoff between maximizing the rate of momentum transfer to the asteroid (i.e., maximizing the fraction of the ion beam intercepted by the asteroid) and minimizing the rate of material sputtered from the asteroid surface that is deposited on the spacecraft. The spacecraft would be configured to enable the electric propulsion system to use of all of the available power from the solar array for transportation to the asteroid. This approach would minimize the flight time to the asteroid maximizing the time available for deflection. Once at the asteroid the spacecraft would be reconfigured to enable electric propulsion system to thrust toward the asteroid with half of the available power and away from the asteroid with the other half. The flight system would continuously enforce equal and opposite forces and zero torques by reorienting the spacecraft and steering the net thrust vector through the time-varying center of mass. This configuration would be maintained until the desired deflection is verified.

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