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DEFLECTION AND DISRUPTION: A COMPARISON OF PLANETARY DEFENSE APPROACHES

Abstract

Although there are a variety of credible planetary defense techniques for mitigating an Earth-impacting asteroid or comet (kinetic impactors, gravity tractors, nuclear explosive devices, etc.), they all fall into two basic approaches: deflection and disruption. An impact occurs when the orbits of the two celestial bodies intersect each other with both bodies in the same location at the same time. Deflection works by altering the impactor's orbit and thereby making the object miss the Earth. Asteroids and comets are both generally "rubble piles," consisting of heterogenous collections of various size particles ranging from fine grains to multi-meter boulders. Since these particles are loosely bound gravitationally with very low cohesive forces, care must be taken to not fragment the body if only deflection is desired. Historically, deflection has been the preferred planetary defense approach with the goal of imparting upon the asteroid or comet a sufficient change in velocity to avoid impact, which is reduced with sufficient warning time, while avoiding fragmentation. However, this may not be possible for previously undiscovered impactors with short warning times, and disruption during terminal Earth approach may be the only viable approach. Disruption primarily works by imparting enough energy to overcome the impactor's internal cohesive forces and gravitational binding energy causing the object to fragment. If the fragments can be made sufficiently small (approximately 10 meters in diameter or less), their impact energy can be absorbed by the Earth's atmosphere. With sufficient warning time, even if an object fragments, the orbit of the barycenter of the collection of fragments can be altered sufficiently to avoid the Earth with the fragments that reach escape velocity being permanently dispersed. Both approaches have positive and negative aspects and can also be combined to provide a versatile hybrid approach. There are many considerations in implementing a planetary defense mission, or a set of missions, ranging from the physical constraints of the asteroid or comet and the technical implementation of the spacecraft and its operations to the practical and geopolitical considerations for the inhabitants on Earth. Additionally, Earth-orbiting infrastructure, unprotected by the Earth's atmosphere, can be affected by a disruption effort. This paper provides a comprehensive comparison of the approaches, taking a holistic perspective to identify the considerations associated with how different technologies and techniques can be implemented to mitigate or eliminate the effects of an Earth impactor through either deflection and disruption, or through a combination of both techniques.