Paper ID: 36839
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ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimization (2) (7)

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MISSION DESIGN AND OPTIMAL ASTEROID DEFLECTION FOR PLANETARY DEFENSE

Abstract

As missions to asteroids become more common and the risk of an asteroid impact becomes more real, as demonstrated by the Chelyabinsk meteor, planetary defense becomes a topic of increasing importance. A deflection mission to an asteroid has the clear objective of safely driving the asteroid as far as possible from the planet. The two most studied deflection mechanisms for cases where time is limited make use of a kinetic impactor or a nuclear explosion device. Past studies have developed different methods for the deflection calculation. The main contributions to this area rely on analytical approximations on the close encounter conditions or heavy n-body propagation of the asteroid's orbit. The method developed here incorporates the trajectory design of the spacecraft with a simple set of two-body propagations to define the asteroid's post-deflection path. This provides a fast and cheap approximation with medium accuracy, suitable for preliminary mission design.

This paper presents a new modeling technique for optimal asteroid deflection that can be incorporated into the spacecraft trajectory design process. The model uses real asteroid ephemerides and calculates the post-deflection trajectory by applying a Lambert fit to correct for the asteroids velocity, at the time of impact, using Keplerian dynamics. Once the natural asteroid path is adjusted for two-body dynamics, the post impact trajectory is constructed using three point parallel shooting. Two of the propagations take place in the heliocentric frame, one forward in time originating at the initial deflection and the other backward in time from the asteroid's entrance into Earth's sphere of influence. The third propagation takes place with Earth as the central body, forward in time from the entrance into the sphere of influence. This method allows for rapid calculation with medium fidelity achieved through the use of the real ephemerides a Lambert corrector, which makes it suitable to be implemented in a trajectory optimization tool. Inside the optimization problem, the close approach distance can be used as the objective function and the spacecraft trajectory can be designed for an optimal deflection. Results show optimal deflection of the fictitious PDC2017 asteroid utilizing two deflection methods, a kinetic impactor and a nuclear explosion device. Low-thrust trajectories were selected for the design as these are more challenging for the optimizer. The optimization tool also allows for the inclusion of real mission constraints and a trade-off between mission parameters, such as launch vehicle, propulsion system and launch window.