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KINETIC DEFLECTION UNCERTAINTIES FOR REAL ASTEROID SHAPES

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ABSTRACT

This paper will perform a survey of known asteroid shapes to determine the systematic errors expected from kinetic impactor deflection attempts due to the asteroid's shape and surface topography. The analysis will apply a novel approach to characterizing stochastic systems to develop figures of merit that describe the level of "control noise" as a function of a given asteroid's shape and topography. While the main focus will be on smaller asteroids with known shapes, the study will also survey other existing asteroid shape models independent of their true hazard to better understand the degree of variation that is to be expected.

One proposed and technically achievable solution to the task of hazardous asteroid mitigation is the use of a projectile as a kinetic impactor to impart a change in velocity on the asteroid and thereby alter its course. A thorough understanding of such an approach's effectiveness requires comprehensive analysis of how uncertain system parameters affect the change in velocity and possibly spin rate of the body. These Quantities of Interest (QOI) depend on both the impact location of the projectile, the surface properties of the asteroid as represented by its β parameter, and the surface topography of the asteroid.

Although a traditional Monte Carlo method could be used to complete this analysis, such an approach is computationally expensive and not conducive to conducting a global sensitivity analysis of the QOI with respect to the random inputs. This paper will instead explore the use of polynomial chaos in combination with analysis of variance (ANOVA) to model the effects of uncertainty in both the impact location and the β parameter on the change in velocity (ΔV). Polynomial chaos provides one alternative to Monte Carlo and allows for the approximation of a stochastic function that is square-measureable with respect to input uncertainties. Given a relatively small number of high-fidelity solutions, a generated polynomial chaos expansion yields a reduced order surrogate model describing the system response. This model then allows for both computationally inexpensive analysis throughout the input

parameter space, as well as global sensitivity analysis of the QOI. Polynomial chaos has been shown previously to be an effective method of characterizing and quantifying uncertainty in the field of astrodynamics, computational fluid dynamics, and other engineering fields.

Once the polynomial chaos model has been validated for a single asteroid, it can be used to conduct relatively rapid analysis of a greater number of asteroids. Specifically, this paper will examine the application of the model to a collection of asteroids of varying shapes, and analysis will be conducted on the uncertainty in the ΔV imparted on the asteroid as a result of its shape. Asteroids can then be classified based on the distribution parameters of deflection maneuvers, including the mean and variance, according to the general shapes of the bodies.

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