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IAA-PDC-15-04-13

METRICS FOR EVALUATING EFFECTIVE DISRUPTION OF HAZARDOUS NEAR-EARTH OBJECTS

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Keywords: *simulation, disruption, computing, deflection, mitigation*

ABSTRACT

This paper presents the results of simulations and analysis investigating the relationships between mass distribution, velocity distribution, and risk of impact for a disrupted near-Earth object (NEO). A preliminary set of metrics for the comparison of such simulations is developed, and a discussion is begun considering what it means to have an effective mitigation strategy.

In moving the science of NEO threat mitigation to effective engineering, many questions transfer from the laboratory to simulations of these ideas applied in a low gravity environment. As our understanding of NEO characteristics becomes better, many research groups have developing simulation packages to investigate strategies to best deflect, disrupt, or otherwise mitigate a threatening mass on an impacting (or near-impacting) trajectory. If all uncertainties regarding the behavior of a particular body under a mitigation strategy could be eliminated, bounded, or modeled, then computer simulations would represent a perfect truth case. Even in this unrealistic scenario, there would still be operational uncertainties related to the actual mitigation mission. This is especially the case when disruption of a target is the intended outcome [1], or for higher energy deflection methods where unintentional disruption is a very real (even likely) possibility [2]. Disruption has been proposed as the method of highest readiness for mitigating the most likely near-term threat of small NEOs, which contribute to dangerous high-altitude airburst events [1,3].

Given the outcome of a particular disruption simulation, the question arises: “Does this represent an effective strategy for mitigation of the target?” Answering this question becomes deceptively complicated. Early attempts focused on a particular sample case, such as the asteroid Apophis or a fictional impactor. In analyzing

these cases for a fixed lead time ahead of impact, it is clear that there is a dominant deflection and/or disruption direction, and that the metric of “total mass remaining on impacting trajectories” is highly dependent on this choice of direction with two degrees of freedom. This is unfortunate because in many cases that metric is the number a policy maker wishes to know before endorsing a strategy. To makes matters worse, some deflection directions (possibly including the optimum direction) are unachievable at any given lead time, and this metric of impacting mass is also dependent on lead time. For this scenario, we focus on investigating some common moments of the mass and velocity distributions represented by post-disruption debris to begin the development of an effective set of computational metrics.

In addition to the limitations investigated in the previous scenario, using the metric of impacting mass is necessarily orbit-dependent. We attempt to characterize this dependence using a large cross section of known NEO orbits parameterized in an (a, e, i) space, which represents much of the variance in observed hazardous objects. This analysis is used to limit the set of measures that are feasible for evaluating the effectiveness of a disruption attempt.

Finally, the author’s thoughts on what parameters are needed to report and recreate an effective mitigation strategy are presented in order to stimulate a dialogue to better understand quantitative figures of “effectiveness” such as those given by NRC and NASA reports.

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