PDC2021
Vienna, Austria

Effects of Momentum Transfer Deflection Efforts on Small Body Rotational State

Daniel Brack[1] **and Jay McMahon**[2]
[1]*Lockheed Martin Space, 12257 S. Wadsworth Blvd, Littleton, CO, USA, 80125, 303-977-9722, daniel.n.brack@lmco.com*
[2]*University of Colorado Boulder, 3775 Discovery Drive Boulder, CO, USA 80303, 303-492-3944, Jay.Mcmahon@colorado.edu*

Keywords: *asteroids, deflection, rotation*

ABSTRACT

The risk of a possible collision of a Potentially Hazardous Object (PHO) has led space agencies and research organizations to explore deflection strategies that would reduce such a threat. Many methods have been proposed for PHO deflection; Those include: nuclear device detonation on or near PHO surfaces, kinetic interception with high relative velocities, gravity tractors, landers with active (thrusters) or passive (solar sails) propulsion systems, mass drivers, and surface ablation high energy beams. These methods seek to slightly perturb the PHO's orbit from its collision course with Earth by introducing momentum into the system, either with a single event or with continuous or semi-continuous efforts. The single event, direct momentum transfer methods of nuclear detonation and kinetic interception are currently at the highest technology readiness levels and apply to both asteroids and comets.

The momentum transfer in single event deflection methods is intended to be linear, usually close to the direction of orbital velocity of the PHO, affecting its orbital energy and momentum. However, an almost inevitable byproduct is the introduction of angular momentum to the PHO's rotational state. This torqueing side-effect is the result of a lever arm between the body's center of mass and deflection interface location on the surface and direction with respect to the center of mass. Either due to unintentional targeting discrepancies or due to operational requirements or limitations, such as the required orbital direction of deflection, or the degree of surface illumination. The ejection of material off the surface also changes the body's mass distribution which, in turn, affect its rotational dynamics.

Past research into momentum transfer deflection has mostly focused its discussion on efficiency in the orbital sense of optimal trajectories, deflection timing, orbit phases, and relative velocity magnitudes and directions, or in analysis of the impact event, focusing on the expected momentum transfer from different types of surfaces and their resulting ejecta. The majority of this research assumes a spherical PHO or an impact normal to the surface with little to no consideration to the realistic small body shapes.

This paper will address the changes to a PHO’s rotational state due to a kinetic impact or nuclear detonation deflection. The paper first uses ellipsoids of different ratios to model the change in PHO rotational state due to deflection efforts. This model takes into consideration the torque that is introduced in the deflection effort as well as the change in moments of inertia due to mass displacement in the deflection. The paper then expands the model fidelity using polyhedral shapes to quantify the affect a kinetic impactor or nuclear detonation will have on a PHO's rotation. The results show various outcomes that mostly depend on the deflection location on a PHO's surface and the subsequent lever arm with respect to the PHO's center of mass. High energy deflection efforts, such as nuclear detonation have the potential to disrupt a PHO's rotation in a catastrophic way, possibly leading it to an unstable structural state.

****

Comments:

This paper was originally presented at the 2019 IAC and published in the AIAA Journal of Guidance, Control and Dynamics. References:

1. Brack, Daniel N. and McMahon, Jay W. (2019). Effects of Momentum Transfer Deflection Efforts on Small Body Rotational State. *70th International Astronautical Congress (IAC,* manuscript number IAC-19,C1,2,2,x50088
2. Brack, Daniel N., and Jay W. McMahon. "Effects of Momentum Transfer Deflection Efforts on Small-Body Rotational State." Journal of Guidance, Control, and Dynamics 43, no. 11 (2020): 2013-2030, https://doi.org/10.2514/1.G004963