Paper ID: 17921
student

ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimisation (2) (7)

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A ROBUST NEAR EARTH ASTEROID MITIGATION CAMPAIGN OF MULTIPLE FORMATION FLYING GRAVITY TRACTORS

Abstract

Amongst the different asteroid deflection concepts proposed, the gravity tractor (GT) appears to be the most promising deflection technique given current technological readiness levels. Typically a GT mission requires at least a few years and possibly up to a decade to achieve a reasonable deflection. For this reason a single GT mission will be subject to considerable reliability issues. Sending multiple gravity tractors (MGT) will therefore greatly enhance the mission robustness but at the cost of the increased complexity in the proximity operations and changes in the characteristics of the tractoring operations. Such a formation-flying MGT mission could however be beneficial for the following points: 1) Design of a gravity tractor is independent of the Earth-threatening asteroid's scale. 2) Given such a uniform design, manufacturing an adequate number of GTs can be performed before the identification of a specific threat. 3) Rather than launching a single 10-ton GT or assembling it in Earth orbit, smaller MGT can be launched easily through smaller launch vehicles. 4) Reliability to complete the mission given the loss of part of the MGT on the way to the target body or during deflection operations.

Previous studies have shown the advantages and improvements that can be achieved by using formation-flying for MGT obtaining larger deflections than a single GT, although these results were limited by the propellant requirements for station-keeping. Additionally, spacecraft formation flying technology presents control challenges which escalate as the number of elements in the formation increases and when considering centralised command. This paper will present different possible configurations of MGT and compare their performance as well as the single GT case. To this end, decentralised control algorithms will be developed to regulate the formation of MGT in order to achieve efficient deflection while optimizing fuel consumption and considering eccentric trajectories for the asteroid. The control paradigm will be based on a combination of artificial potential fields and linear quadratic regulators. The first element will prevent collision between the elements of the formation while the second element will be used to drive and maintain the desired configuration and to minimise the functional cost – in this case fuel consumption. Furthermore, analysis and simulation of the orbit propagation of the asteroid will be performed by calculating time and distance of collision with Earth, epoch time required for the MGT to intercept the asteroid and the necessary delta-v budget for MGT orbital manoeuvring.