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ASTEROID BELT MULTIPLE FLY-BY OPTIONS FOR M-CLASS MISSIONS

Abstract

The exploration of the asteroid main belt is of the utmost importance to address many of the fundamental questions in modern planetary science (e.g., Solar System formation and evolution theories). This paper investigates potential opportunities for medium-class asteroid belt survey missions in the timeframe of 2029+. The launch as assumed here corresponds to that of the forthcoming ESA call for medium class mission proposals. The study has been developed in support of the CASTAway Asteroid Spectroscopic Survey mission proposal, which is to be submitted to the aforementioned call. CASTAway envisages the launch of a small telescope with relatively straightforward (i.e. high TRL) remote sensing instrumentation to detect asteroids at a range of 0.1-0.5 AU. The spacecraft would then head towards the main belt with the following objectives: The mission should test Solar System evolution theories by; 1) performing a statistical survey of small asteroid belt objects previously unsampled (<1 to a few tens of metre-sized); 2) providing compositional information for 1000s of objects by obtaining spectral data over a wide range of wavelengths, including key regions not observable through the Earth's atmosphere; 3) studying the morphology and geological history from close flybys of a targeted sub-set of objects, at least doubling the number of currently visited main belt asteroids within one single mission (>9 fly-bys). This paper presents a challenging multi-objective optimization problem and discusses the feasibility of such a mission concept. Firstly, a set of competing performance indices are defined that consider the cost of the mission, the quality of the survey (i.e. number of new detections and spectral data) and the number of asteroid fly-bys. The fly-by combinatorial problem is then tackled using the Minimum Intersection Orbital Distance as an heuristic filter to prune out unfeasible targets. Genetic and evolutionary algorithms are used to globaly optimize impulsive transfers, considering also planetary fly-bys, deep space and Δv-leveraging manoeuvres. Low-thrust trajectories are considered, although long thrusting periods impact negatively in the available operational time for remote sensing operations. Shape-based methods are used to globally optimize the low thrust controls, while the GPOPS-II and IPOPT transcribe the continuous-time optimal control problem and solve the subsequent nonlinear programming problem, respectively.