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ANIME ASTEROID CUBESAT MISSION CONCEPT AND RENDEZVOUS PHASE: PROGRESSIVE HYPERBOLIC ARCS DESIGN FOR RADIO-SCIENCE AND CLOSE OBSERVATION

Abstract

Over recent years, there has been a growing emphasis on planetary defense missions aimed at investigating small celestial bodies that pose potential collision risks with Earth. The ANIME mission is part of this effort, financed by funding from the Italian Space Agency (ASI) in the framework of the ALCOR program, and developed in a consortium guided by INAF and including Università di Bologna, Politecnico di Torino, and Politecnico di Milano. In particular, ANIME is a 12U CubeSat mission currently in Phase A having as objective a rendezvous with asteroid 2000 SG344, the largest object known to have a better than 0.1% of impacting Earth. The scientific objective is to explore the target to collect far and close-range measurements via two optical payloads and performing several radio-science measurements. During its interplanetary travel towards its final destination, ANIME will also fly by two additional potentially hazardous asteroids, still to be defined, in order to collect additional measurements of NEA objects.

The proximity trajectory design after rendezvous with 2000 SG344 is driven by the imaging and radio-science requirements specifically selected by the scientific team. The proposed strategy manages to satisfy the scientific requests while exploiting the natural dynamics of the system to minimize fuel consumption, a critical aspect for the very limited resources of a 12U CubeSat mounting only an electric propulsion unit. In addition, a disposal strategy is planned to have a free-falling trajectory towards the surface of the asteroid while ensuring a limited touchdown speed, further enhancing the overall scientific return of the mission. The design starts from the definition of progressively approaching hyperbolic arcs and station keeping maneuvers via a single shooting optimization algorithm with impulsive approximation of the thrusting arcs. Then, the trajectory of the entire phase is refined by removing the impulsive assumption computing the corresponding low thrust control profiles with Sequential Convex Programming techniques.

The trajectory output is then used as reference and numerically tested in several Monte Carlo analyses with a high-fidelity orbital propagator including expected uncertainty sources deriving from the platform and the poorly known environment. The results demonstrate that the designed strategy satisfies all the scientific requirements for imaging and radio-science while still complying with the stringent constraints given by the platform, allowing to state the feasibility of the ANIME deep space CubeSat mission concept.