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Publication date
2022

Document Version
Final published version

Citation (APA)
Casini, S., Cervone, A., Monna, B., & Visser, P. (2022). *Line-of-Sight Navigation Observability Analysis for Near-Earth Asteroids Exploration with CubeSat*. Abstract from 73rd International Astronautical Congress, IAC 2022, Paris, France.

29th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Interactive Presentations - 29th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (IP)

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LINE-OF-SIGHT NAVIGATION OBSERVABILITY ANALYSIS FOR NEAR-EARTH ASTEROIDS EXPLORATION WITH CUBESAT

Abstract

CubeSats represent a promising solution for low-cost deep-space exploration, especially for Near-Earth Asteroids (NEAs) missions. In this framework, autonomous navigation is a viable option to improve CubeSat capabilities for deep-space exploration. Line-of-sight (LoS) navigation is a technique based on the observation of planets with cameras, to estimate the spacecraft state in deep-space. It is attractive for small-spacecraft missions, as it does not require additional instrumentation, since cameras or star-trackers are usually carried on-board. Feasibility of exploiting LoS navigation for NEAs exploration is investigated, by analyzing the relative geometry between observable planets and NEAs at their ascending and descending node passages. In literature, an index has been formulated to quantify analytically the navigation performance in the case of simultaneous tracking of two bodies, and it is used here to investigate LoS navigation applicability to NEAs exploration scenarios. The index depends on the relative geometry of the observation. The lower its value, the higher the navigation accuracy. The NEAs dataset has been retrieved from NEODys-2, a web-based database containing 26822 orbital parameters. NEAs ephemerides have been propagated for the period 2022-2032. The spacecraft has been assumed coincident with the target NEA at the nodes, as the distance asteroid-spacecraft during the encounter is in the order of few hundreds of kilometers. The observation of the six inner planets (from Mercury to Saturn) is considered. The performance index has been calculated for each pair of planets at each node passage, assuming all the bodies whose line-of-sight direction has an angular separation of at least 30° from the Sun direction are visible (common Sun exclusion angle for star trackers). The result consists in a list of NEAs, whose geometry is appealing for LoS navigation, and that can be used for further analysis to design trajectories to reach these bodies with CubeSats. The performance index ranges from $\sim 10^{15}$ to $\sim 10^{24}$. Analyzing a total of 265067 node passages, in less than 1% the index could not be computed because either none or only one planet was visible, while in almost 13% of the cases all planets were observable. It is shown that for 870 NEAs, the performance index is smaller than 10^{16} at least once in the decade under analysis, and for those higher accuracy of the LoS navigation is expected. Test trajectories are generated for the first asteroids in the list, and navigation simulations, using CubeSat hardware characteristics, are carried out.