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A REVIEW OF CONJUNCTION DETECTION AND COLLISION PROBABILITY ASSESSMENT TECHNIQUES FOR THE USE IN A CISLUNAR SIMULATION FRAMEWORK

Abstract

With increasing interest in lunar orbits for future missions, including the ARTEMIS program and the reintroduction of human spaceflight to the moon, enabling mission safety in cislunar space is crucial. The planned lunar missions will lead to a growing number of objects around the moon and in cislunar orbits, increasing collision risks. Because the space surveillance and tracking capabilities in cislunar space are less sophisticated than for Earth orbits, collision probability thresholds that are used as decision criteria for collision avoidance (COLA) actions in Earth orbit can be inconclusive in the cislunar regime. In addition, without an atmosphere, debris generation events in lunar orbit have the potential for expansive consequences, affecting both Earth and Moon trajectories, as well as operations on the lunar surface.

Recent studies concentrate on investigating space debris evolution resulting from break-up events in specific cislunar orbits, assessing the threat of collision by e.g. annual or monthly collision probability or by residence time in a designated orbital area. So far, only limited consideration has been given to quantifying collision probability or risk for distinct conjunction scenarios in the cislunar regime. Operationally, COLA manoeuvres have even been conducted based on orbit crossing distance instead of collision probability.

As today there is no comprehensive understanding of collision risks and frequencies of conjunction events in cislunar orbits, the Cislunar Risk Assessment and Conjunction Detection (CLARA) framework is envisioned as a simulation framework for the comprehensive study of collision risks in cislunar orbits. It will enable the analysis of conjunction frequencies and collision probabilities in relation to population, covariance and accepted decision thresholds. Thereby it can serve as a tool to operators, regulators and other space stakeholders, e.g. for preliminary mission design, the analysis of sensor network architectures and required frequencies of observation, or to investigate the impact of potential space debris mitigation strategies.

This paper explores the limitations of the current available solutions and approaches to conjunction detection and collision probability assessment for cislunar missions. It presents an overview of current regime-specific and regime-unspecific approaches and a structured analysis of their transferability and usability for a cislunar simulation framework, concluding in the identification of further research and development needs. The paper also presents the conceptual design of the CLARA framework and intends to engage relevant stakeholders for the further definition and development of this tool.