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MOONDB: A DATA-DRIVEN INVESTIGATION OF PAST, PRESENT, AND FUTURE LUNAR MISSIONS FOR SUSTAINABLE EXPLORATION

Abstract

The history of lunar exploration is full of remarkable achievements and technological marvels, but it has often prioritized progress over long-term sustainability. In the early decades of space exploration, little thought was given to the fate of artificial objects left in orbit or on the lunar surface. As a result, spacecraft, launcher parts and fragments remain within the Earth-Moon system or in heliocentric orbits. Some are well-documented, while others remain largely untracked, posing potential risks to future cislunar missions. Interest in the Moon has grown, with plans to establish a permanent human presence in lunar orbit and on its surface. As these activities approach, understanding our past is essential: first, to assess the existing environment and the risks posed by unidentified objects; second, to ensure that future exploration is conducted more sustainably.

The Lunar Mission Database (MoonDB) was created as a public resource to catalog all historical lunar missions and support research on sustainability. Built from NASA historical data and various archival sources, MoonDB serves as a foundation for analyzing past lunar exploration efforts and understanding their long-term impact. This paper first provides a statistical overview of these missions, highlighting key trends and patterns in lunar exploration. It then shifts focus to the present, examining the artificial objects still in orbit, particularly those that pose the greatest risks. Many of these spacecraft are effectively unobservable, and their locations can only be reconstructed by cross-referencing past records with tracking data. The paper also explores the potential applications of integrating MoonDB with other object databases and mission recording systems, improving how we track and analyze these relics.

Finally, looking toward the future, the discussion addresses the missions planned for the coming years and their approach to sustainability. Then, the need for a more structured approach to tracking and managing space objects. One proposed solution is the establishment of a comprehensive registration system for lunar and orbital debris, ensuring that future missions have access to reliable historical data. As humanity enters a new era of lunar exploration, planning for a permanent presence and expanded scientific and industrial activities, such measures will be essential for mitigating risks and ensuring a sustainable presence beyond Earth. The Lunar Mission Database serves as a crucial step in this direction. Understanding the past is necessary to navigate the future with greater awareness and responsibility, and make informed decisions that will shape the next chapter of space exploration.