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WATER DEMAND FORECASTING IN CISLUNAR SPACE USING SYSTEM DYNAMICS APPROACH

Abstract

In recent years, the complexity and diversity of Cislunar space has been increased as the number of stakeholders has grown. This trend is expected to continue and intrensify over the coming decades. This growing divesity and complexity are anticipated to significantly influence various aspects of activities associated with the utilization of outer space around the Earth and Moon particularly the demand for transportation between the Earth and Cislunar space. As Cislunar space becomes more critical for future space exploration and commercial use, accurately predicting transportation demand is vital for its efficient utilization. Among the factors influencing this demand, forecasting the need for water—a key resource for sustaining human space activity and operations in outer space—is especially important. Water is essential for life support systems, propulsion for launches to the Earth or to the Mars, and in-situ resource utilization (ISRU), which will be required for sustainable lunar missions following the Artemis program. However, only a few of standardized methodology currently exists for predicting water demand in Cislunar space. This challenge arises from the need to integrate complex and interdependent factors, such as ISRU for water extraction from lunar resources, transportation logistics, and potential water recycling systems in a Moon base. The development of a predictive framework capable of accounting for these factors is essential for informed decision-making regarding future water supply strategies. To address this, this study aims to develope a system dynamics-based model for forecasting water demand in Cislunar space, considering both lunar surface water production and water recycling processes. Through simulations under various scenarios, the study seeks to provide insights into the long-term feasibility of water supply solutions for lunar and Cislunar activities after the Artemis program. The study begins with the identification and analysis of causal relationships driving future water demand in Cislunar space, considering mission frequency, space station size, technological advances, and resource utilization. Based on these relationships, a predictive model is constructed, simulating potential water demand under different conditions. Simulations are conducted under both optimistic and pessimistic scenarios, revealing that under favorable assumptions, lunar water demand could be met through a combination of ISRU-based water extraction and recycling technologies. Additionally, to validate the model's reliability and applicability, a comprehensive literature review and structured group interview were conducted. The results confirm the relevance of the model in forecasting Cislunar water demand and its potential to inform strategic lunar exploration planning.