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Systems and Infrastructures to Implement Sustainable Space Development and Settlement - Systems (2A)

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METHOD FOR COST OPTIMIZATION AND BREAKEVEN ANALYSIS OF A LUNAR IN-SITU RESOURCE UTILIZATION OXYGEN GENERATION SYSTEM AND SUPPORTING MISSION ARCHITECTURE.

Abstract

Designing profitable logistics architectures is necessary to establish a robust lunar economy. It is the goal of the National Aeronautics and Space Administration (NASA) to commission self-sustaining lunar infrastructure through the Artemis missions, including a carbothermal reactor system that would produce local oxygen from ilmenite lunar regolith. A method for minimizing the operational costs and increasing the profitability of such space systems will be required if commercial companies expect to generate a profit from their services. To address this, in a previous study, a technical model for profitability was derived and developed as a computational tool called the Cost model for Space system Operations (COST-O). In this paper, a manual cost optimization method for space system mission architectures, with respect to logistics and technical system design was derived, demonstrating the selection and iteration of a design vector for a commercial lunar in-situ resource utilization (ISRU) liquid oxygen generation system, including iterating on the system's open versus closed loop capabilities, and the reduction agent used by the reactor. The concept of operations for which these architectures were based on improved in fidelity by including crew members for system commissioning and maintenance operations, and in-orbit refueling of the launch vehicle. These mission architectures were modelled and simulated in SpaceNet which first analyzed for feasibility. The SpaceNet data for the resulting feasible architectures was processed by COST-O. The COST-O data was then used to make financial forecasts, such as the breakeven design rate and timeline. The decision variables were analyzed for areas of high cost sensitivity, and an uncertainty analysis was performed. The results suggest that for a commercial lunar ISRU oxygen generation system, an architecture supporting a closed loop design, using Starship as the launch and landing vehicle, a prepositioned stockpile of resources at the lunar surface, and a hydrogen reduction agent is most cost optimal, with a production rate of twenty thousand kilograms per year, and an operating cost of one million USD per kilogram. Profitability was achieved for this design rate at the current market price of 1.2 million USD per kilogram by the end of the first year of steady state operations. Attempts to minimize this operational cost further should improve the recyclability of the system. Future work should evaluate added robustness to the architecture by delivering multiple systems and should model deliberate cargo packing decisions.