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DECISION SUPPORT SYSTEMS FOR LUNAR IN-SITU RESOURCE UTILIZATION DESIGN AND OPERATIONS UNDER UNCERTAINTY

Abstract

The production of critical mission consumables such as oxygen, water, and propellant from resources in the lunar environment is a crucial first step to establishing a permanent and sustainable human presence on the surface of the Moon. The lessons learned from achieving this milestone would also be invaluable as we look towards crewed missions to the martian surface. The innate remoteness, uncertainty, and harsh nature of the lunar surface environment coupled with long planned mission lifetimes necessitates the development of novel ways to operate lunar resource processing infrastructures. This paper explores the development and testing of different decision support systems designed to aid human users in the sustainable operation of lunar in-situ resource utilization (ISRU) systems under uncertainty. These decision support systems take into account key sources of uncertainty in the lunar operating environment and use a Monte Carlo approach to recommend actions most likely to result in a beneficial outcome quantified using novel sustainability indicators. This paper utilizes a serious game approach to achieve this, where a simulation platform is used to allow both human users and artificial agents to make the strategic level decisions behind a pilot lunar ISRU facility with the aid of different decision support systems. A flexible ISRU plant design is proposed, using a real options approach to achieve desired outcomes in the long term and under uncertainty. This paper also attempts to consolidate different sizing methods for ISRU subsystems into a single comprehensive sizing methodology that is used in the design of the simulation platform developed. This allows the findings of the simulation studies performed to be more validated and showcases the potential real world merit of the decision support systems evaluated. It is described how the decision support systems developed have more use cases beyond lunar ISRU, and application areas where they could studied in, such as terrestrial mining, are discussed. Future experiments that could be run using the simulation and decision support tools are also described, such as further exploring the optimal allocation of operational, tactical, and strategic level decision making between human users and decision support system assisted agents.