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AUTONOMOUS IN-SITU RESOURCE UTILIZATION ON THE MOON: A FEASIBILITY STUDY OF 3D PRINTING WITH LUNAR REGOLITH

Abstract

Expanding human presence on the Moon and across the solar system relies on developing effective methods to utilize in-situ resources, particularly on the Moon. This feasibility study examines the potential of an autonomous 3D printing robotic system to perform In-Situ Resource Utilization (ISRU) on the lunar surface, a concept that is gaining significant interest for its capacity to reduce mission costs and enhance sustainability. By leveraging lunar regolith to manufacture tools and components, this approach could decrease dependence on Earth-supplied materials, addressing one of the primary logistical challenges in long-term lunar exploration.

This study explores the adaptability of autonomous 3D printing using advanced sensor-based decision making for selecting and processing suitable regolith samples, which contain essential metals like titanium and aluminum. The system includes a rover capable of extensive sampling and real-time analysis of regolith quality, allowing it to identify materials optimal for additive manufacturing. A stationary processing unit then extracts these metals and feeds them into a custom-built metal 3D printer to produce components. Tele-operable oversight from Earth will provide remote support, enabling adaptive response to environmental changes or material inconsistencies.

A key focus is on sustainable power management, utilizing solar energy for both the rover and processing units, thereby reducing resource strain on lunar operations. Novel testing protocols will be applied to evaluate the structural integrity of printed components under lunar conditions, ensuring that they meet the standards for immediate and long-term use.

This study aims to demonstrate a complete ISRU cycle on the Moon, from regolith sampling and metal extraction to component production and testing, establishing a foundational model for autonomous resource utilization and manufacturing on extraterrestrial surfaces.