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RECYCLING AND PROCESSING METALS ON THE MOON: A FRAMEWORK TO SUPPORT A
SUSTAINABLE LUNAR ECONOMY

Abstract

The METAL framework (Material Extraction, Treatment, Assembly Logistics) was proposed for Luna-10, a lunar infrastructure study led by DARPA. This proposal outlines a transformative approach to the future lunar economy and was selected as one of the cornerstones of the Luna-10 study. The framework pioneers scalable, sustainable infrastructure for the Moon, emphasizing the critical role of in-situ resource utilization (ISRU) for metal and metalloid material processing. By integrating a comprehensive capability chain—spanning Prospecting, Extraction, Mobility, Smelting, Foundry, Mill, to Factory stages—METAL enables the local production of foundational industrial products such as beams, rails, sheets, struts, wires, and mining equipment. This strategy not only dramatically reduces the mass and cost of materials transported from Earth but also underpins the development of a self-sustaining lunar economy. An important aspect of the METAL framework lies in its recycling capabilities, which DARPA recognized as essential for the effective scaling of lunar infrastructure. By facilitating the repurposing of materials, METAL enhances the efficiency and sustainability of lunar operations and sets a precedent for closed-loop manufacturing processes in extraterrestrial environments. This holistic approach to lunar industrialization positions the METAL framework as a key enabler for long-term human presence on the Moon, offering a scalable blueprint for extraterrestrial resource management and infrastructure development. This work discusses the challenges and opportunities of the metal processing value chain and its impact on a future sustainable lunar economy.