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A COMPREHENSIVE FRAMEWORK FOR OFF-EARTH MINERAL AND CHEMICAL RESOURCE ECONOMICS

Abstract

Scientific and technical work on the potential extraction and use of off-Earth minerals and chemicals has been conducted at least since the 1970s, as a method of lowering the costs of activities in space and facilitating plans for the extension of human activity into the solar system. There is an increasing amount of evidence of many potential fuel sources in the form of water ice or hydroxyl radicals throughout the solar system, including on or within the Moon, Mars, Mercury, comets, many asteroids, and ubiquitously in the outer solar system beyond the ice line.

This is leading to a rapid increase of interest from nations, space agencies and private companies in characterising, quantifying, accessing, extracting and using these potential resources. However, research on the topic off-Earth *in situ* resources is taking place largely on very focussed topics and without the context of mature technical and economic frameworks analogous to those used to justify commercial investment within the terrestrial mining, oil and gas industries. Such a framework is critical for guiding systematic scientific and engineering priorities and methods for off-Earth resource projects, to provide the quantitative data needed to minimise technical and economic risks and to justify financial investment.

A novel framework for Off-Earth Mineral and Chemical Economics (OEMCE) meeting this need is presented here. The framework is derived at a high level from the economics of terrestrial mining and minerals industries, although the details of its components are by necessity radically different from methods in terrestrial mineral economics. The framework captures essential stages and activities of an Off-Earth Resource Extraction Cycle that begins with Market Analysis and then proceeds through Prospecting, Resource Modelling and Analytics, Orbital and Trajectory Logistics, Monetisation and Business Modelling, and Resource Extraction Process Design, Development, and Operations. The cycle is contextualised by facilitating hardware and software technologies, and legal and social factors. Progressing through the cycle reflects increasing understanding of a specific resource, its potential for commercial utilisation, and increasingly constrained quantification of commercial and technical risks. Each element of the framework is highly complex and continues to be addressed by numerous research projects, studies and reports, for which the OEMCE provides an integrating framework. All the elements of the framework must differ in their details from those in terrestrial mineral economics due to radically different short-term markets, structural, compositional and gravitational resource features and environments.